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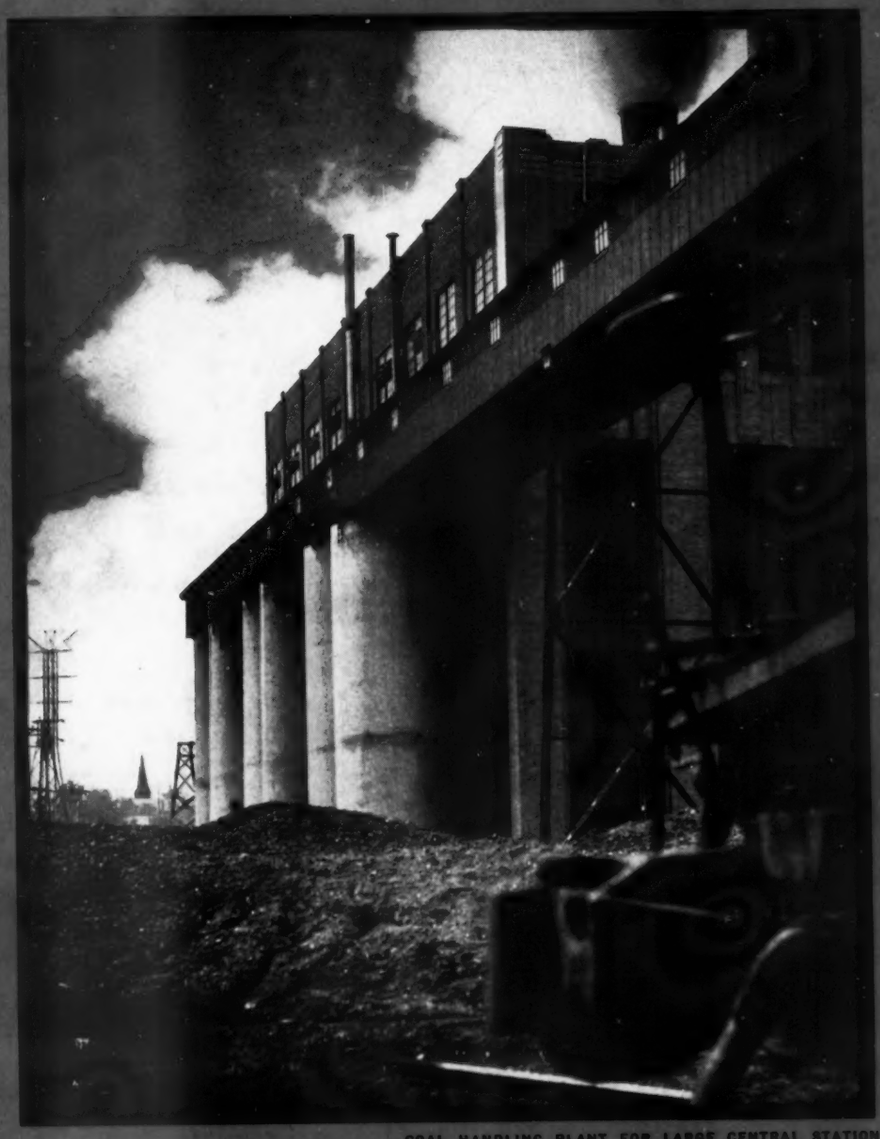


COAL HANDLING PLANT FOR LARGE CENTRAL STATION

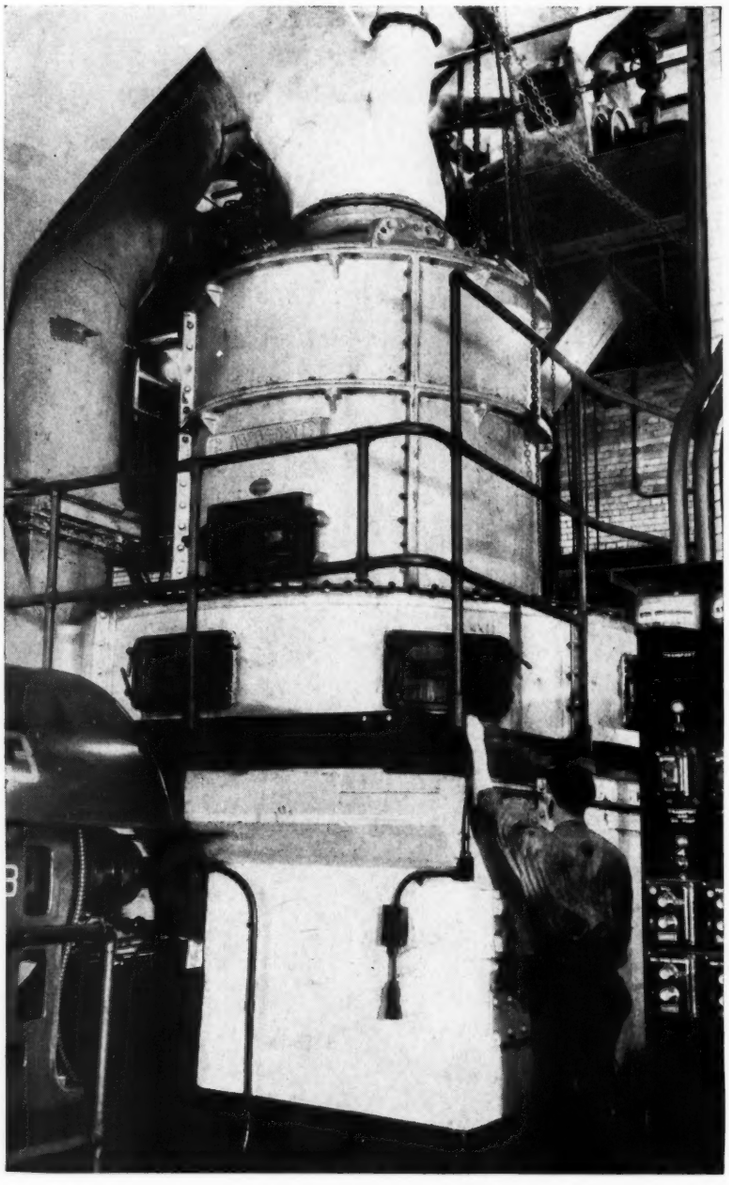
The Design of Steam Generating Plants
By F. H. ROSENCRANTS

Single Pass Boiler Installation at Duluth Station
By A. H. KRAUSS

OTHER ARTICLES IN THIS ISSUE BY
OTTO de LORENZI • DAVID MOFFAT MYERS • FRANK S. O'NEIL • A. J. MOSES • DAVID BROWNLIE

46 Tons per hour

from a 25 ton mill



One of four 25-ton Raymond Roller Mills installed in the East River Station of the New York Edison Company in 1929. The complete pulverizing plant consists of four 25-ton and two 15-ton Raymond Mills.

A 25-ton Raymond Roller Mill pulverized 46.38 tons of Pocahontas coal per hour in tests conducted at the East River Station of the New York Edison Company. This capacity, which is 85.5 per cent above the rated capacity of the mill, was made with a mill and exhauster power comsumption of 6.8 kw. hr. per ton.

Records of this plant for one year show an availability factor of 95 per cent for the four 25-ton Raymond Mills installed and a total operating cost of 9.84 cents per ton of coal pulverized by these mills and by two 15-ton Raymond Mills. The latter figure includes operating and maintenance labor, maintenance materials and lubrication for pulverizing, drying and transporting.

Raymond Roller Mills are available in various sizes for rated capacities ranging from less than 2 tons up to 50 tons or more per hour.

The total rated capacity of Raymond Mills installed in American steam plants is 22,700,000 tons of coal per year.

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BOILERS - AIR PREHEATERS - STOKERS - PULVERIZED FUEL EQUIPMENT - WATER-COOLED FURNACES

COMBUSTION

VOLUME THREE • NUMBER NINE

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H. STUART ACHESON, *General Representative* — CHARLES MCDONOUGH, *Editor* — F. H. ROSENCRANTS, *Associate Editor*

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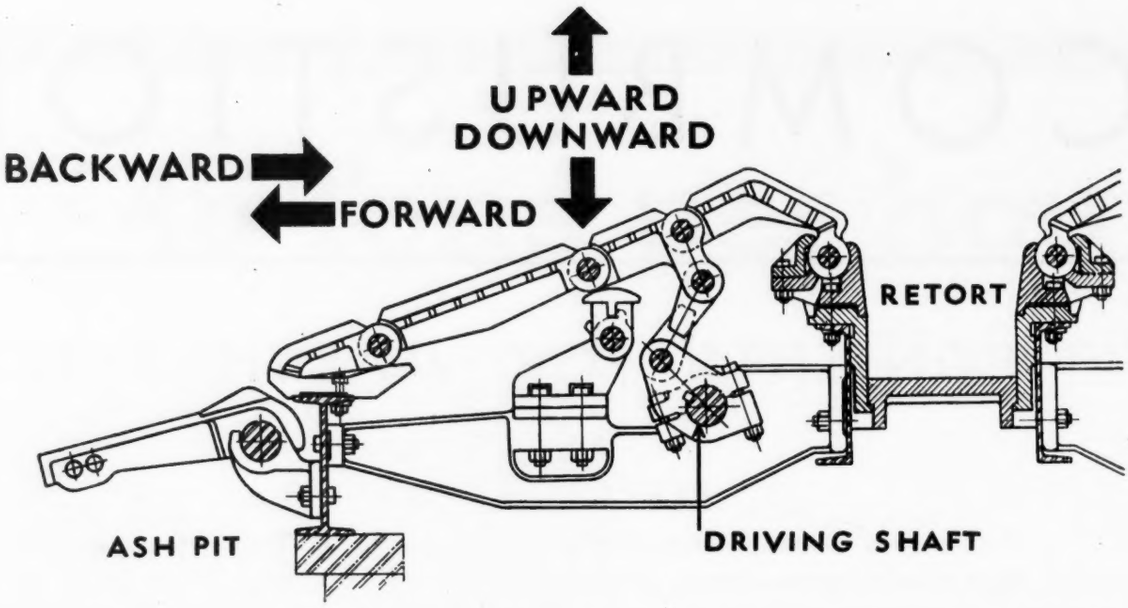

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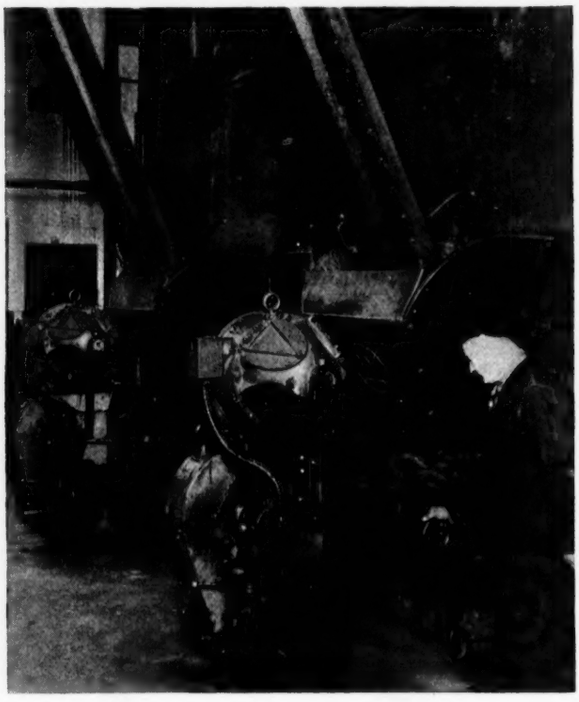

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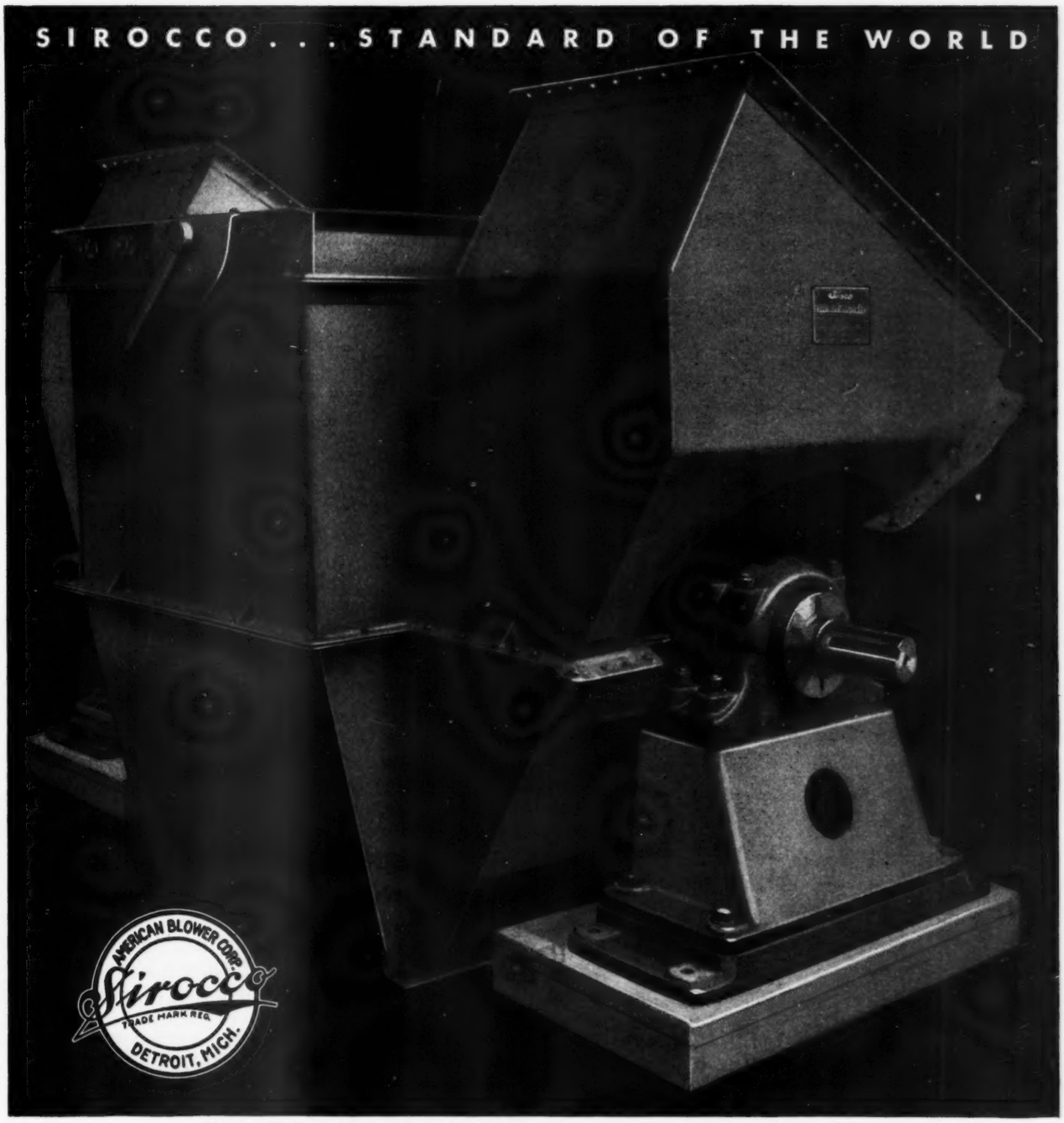

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EDITORIAL

Now, is the Time

A STORY has recently come to our attention, the truth of which we cannot vouch for, but, since it is quite credible and also serves to illustrate an important point, we are setting down the facts as we recall them. It seems that the management of a certain manufacturing company reached the decision that it must dispense with the services of twenty employees whose combined salaries totalled $4,000 per month. But just as the axe was about to fall, someone had the happy thought that if these men could find some way of saving the company the amount of their salaries, by means other than the elimination of their names from the payroll, the result, financially speaking, would be the same and the local unemployment problem would remain that much less serious. So the individuals about to be fired were told that they were at liberty to go out into the various departments of the manufacturing plant and if within a month they could find ways of saving an amount equivalent to their salaries they would retain their jobs. Not only did they succeed in meeting this initial objective, but within a comparatively short time, the savings effected as a result of their efforts totalled $25,000 per month.

The chronicler did not say whether or not the men responsible for this achievement received a bonus, but he did point out that the principal part of this saving was in the production of steam and its distribution to the various departments of the plant, which obviously was a fairly large one.

And herein lies the point of our story. We are convinced that many industrial plants can effect comparable savings through analysis of their methods for producing and distributing steam both for power and process work. And in these days when the maintenance of employment is such a vital factor, not only to the individuals concerned and their families but to the nation as a whole, there seems to be no excuse for not taking the steps necessary to procure such savings wherever the possibility exists. In some instances substantial savings can be obtained with very little capital expenditure. In other cases the initial expenditure required may be fairly large. But even in the latter case, many companies are in a position easily to justify the investment especially at this time when the purchasing power of money expended in this way is greater than it has been for many years past and greater than it is likely to be for a long time to come.

It is not at all unusual for a modern mechanical stoker to pay for itself in one year or less and a return of 100 per cent is one that no one who can find the money can afford to delay about. There is a large number of industrials which could go to higher pressures and provide all or practically all of their power as a by-product of process steam at a fraction of its present cost. There are many others which could replace six or eight obsolete steam units with two or three larger modern units with savings that would pay the entire cost in from two to four years and with the additional advantage that they could capitalize these savings at once and thus be in a position to meet present-day competitive price conditions more effectively.

In short, there is an opportunity for savings in steam and power production costs which rightly commands the immediate consideration of the industrial plant executive. And those executives who take advantage of this opportunity are not only serving their present best interests but are placing their companies in a position to take full advantage of an improvement in business conditions when the turn comes. Furthermore, they are doing this at a time when it can be done most carefully and for the least money. That is, they are if they don't wait too long. *Now, is the time.*

Fumaroles

IN a certain part of Tuscany, Italy, there is an area of about 100 square miles where natural boilers in the bowels of the earth provide large quantities of steam which is liberated through vents in the earth's surface called fumaroles. In recent years Italy has been making increasing use of this steam for power purposes not only taking it from the fumaroles but drilling additional holes to considerable depths. Apparently, there is practically no interconnection between these subterranean boilers as the pressure is in no way affected by increasing the number of outlets.

The steam as it comes from the wells has a temperature ranging from 320 to 375 deg. fahr. and consists of 96.5 water vapor the remaining constituents including some boric acid and ammonia. It is first delivered to low-pressure turbines and then treated for recovery of the boric acid and ammonia.

In commenting upon this interesting development the November, 1931 issue of Compressed Air Magazine points out that in Alexander Valley, 100 miles north of San Francisco, a well was drilled nine years ago which gave steam at a pressure of 62 lb. per sq. in. Two additional wells were drilled two years later and although two of these three original wells are but 48 ft. apart, the difference in steam pressure is only two pounds. It has since been estimated that 1000 wells could be drilled in this valley without reducing the original steam pressure.

The Design of Steam Generating Plants

PART I

By F. H. ROSENCRANTS

Consulting Engineer

Combustion Engineering Corporation

New York

COMBUSTION takes considerable pleasure in presenting to its readers this article, the first of a comprehensive series on steam plant design. The author has been identified with the design of steam plants both in this country and abroad for many years past. Readers of COMBUSTION will recall his valuable article "Heat Cycles and Relative Efficiencies" published in the May, 1931, issue. His paper, "Practice and Progress in the Combustion of Coal for Steam Generation" received the 1928 award of the British Institute of Electrical Engineers for the most valuable paper on any subject presented that year . . . The articles comprising this series will deal in logical sequence with the essential problems of steam plant design in so far as they apply to fuel, fuel preparation and burning equipment, steam generating equipment, and to auxiliary, control and instrument equipment. This article is written to set the stage for those that follow and to give to the reader an appreciation of the many problems incident to the design of steam generating plants. The steps required in the solution of these problems and the principles involved will be set forth in succeeding articles which will also present specific design studies covering a range of typical installations.

THE president of a large public utility company once made the remark that if he could get his fuel for nothing, he could afford to reduce the average rate per kw-hr. sold by 10 per cent. The truth of this statement is apparent when it is considered that in a normal case the fuel cost is 0.25 cents per kw-hr. and the average selling price for the system output about 2.5 cents. This remark was made in the course of a statement, the intent of which was to emphasize the predominant importance of reliability and continuity of service and that only a small sacrifice in reliability could be justified in an effort to obtain even an appreciable gain in efficiency. The statement applied primarily to the problems confronting the public utility plant, but in the majority of cases it could be applied with even greater force to the industrial installation. In the industrial plant, the fuel used in the production of steam represents even a lesser per cent of the total selling price of the product than is the case with the electric supply business, and, while a failure of steam supply is not so damaging to the reputation of the industrial as to the public utility company, the actual loss to the company resulting from curtailment of factory output or from interruption to a continuous process may easily be much greater.

The reliability of a boiler unit as a whole is no greater than that of the least reliable essential element of the assembly. To insure reliability, therefore, necessitates that no essential element be incorporated, the reliability of which has not been established in practice. With reliability the ultimate goal, the temptation to experiment on a major scale must be avoided. Having complied with the above requirement the reliability of the plant from a design and construction point of view becomes a matter of perfection in detail of design, manufacture and erection.

In the course of an extensive investigation under the auspices of the National Electric Light Association, covering many plants of widely varying types, a prominent engineer associated with the investigation stated that their findings indicated that plant reliability and continuity of service depended more upon the perfection of detail in design, manufacture, erection and operation than on the type

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of plant. Perfection in these respects is attained only as a result of extensive experience by competent men and organizations.

Fortunately, there is a legitimate field for experimentation, without which there would be little or no progress. The wise owner or designer will, however, select his projects on which to indulge in experiments with discrimination. The rapidly growing industry requiring frequent additions to its steam generating facilities, either in the form of additions to existing plants or in the form of new plants, offers the best and most justifiable opportunities. The large electrical system, having many plants electrically interconnected, and in the process of rapid expansion, offers the ideal situation. In such a case experimental work may be undertaken on a comparatively large scale without endangering the service as a whole and even though the results of the initial experiment may not be economically justified, the knowledge gained, when applied to the installations which follow, results in economies which amply compensate the initial loss. Such is the path of progress.

By contrast, the industrial enterprise, whose initial steam generating plant is designed and constructed to care for its steam requirements for many years to come, has little justification for staking the success of the enterprise upon the success of an experimental steam generating plant. In such a case, design should conform to well-established practice. Reliability should be the keynote. Simplicity is usually an aid to reliability and often may be secured at the cost of a few per cent in efficiency. It frequently will, however, be worth the sacrifice.

A further consideration which the designer will do well to bear in mind is the character of operating organization to which the plant will be intrusted. A highly competent operating organization may justify the adoption of plant features in one instance which would be highly inadvisable if the plant is to be placed in the hands of an operating organization of poor or indifferent ability.

Second only in importance and going hand in hand with reliability is the factor *adequacy*. The plant which can not quite reach the capacity requirements, or which can only do so by supercautious operation and the stressing of the equipment to the last per cent of its capacity to function, is in as much trouble, or perhaps even more, as the plant which occasionally fails to function altogether.

The fact that a plant does not operate with record fuel economy or that it has cost in its construction more, in the opinion of the owners, than it should have, may be cited as points justifying criticism of the designer. Such criticisms seldom arise, however, in connection with plants which have proven themselves consistently reliable and adequate in all of their features to meet or exceed the anticipated requirements. Conversely, the absence of these two factors, i.e., *reliability* and *adequacy*, to any marked extent is damaging to a high degree to the reputation of those responsible. Any virtues which the plant may possess in terms of low cost or high fuel economy, will be but small compensation.

While considerations of the factors *reliability* and *adequacy* will be uppermost in the minds of successful designers, these same designers will, and indeed must, have an open mind to new developments and sufficient technical knowledge and judgment to safely take advantage of them and thus to contribute to the progress of the art. Advanced designs may be undertaken by such men without undue risk. They are the leaders of their profession. To them the industry is indebted for the sound, substantial and rapid rate of progress which has characterized developments of the past decade.

Fundamental Data

Before attempting any conception of the design of a new steam generating unit, full information must be obtained covering all items on which the design is to be predicated. The essential items are:

1. Steam capacity per hour for continuous service.
2. Maximum capacity per hour for short period or peak load operation.
3. Annual load factor.
4. Steam pressure.
5. Total steam temperature or superheat.
6. Feedwater temperature.
7. Analysis of feedwater supply.
8. Kind and character of fuel supply.
9. Cost of fuel or fuels on a B.t.u. basis.
10. The location of plant.

Capacity and Number of Units

The first item for consideration is the number of boiler units to be installed. If continuity of service must be an inherent feature, then adequate spare equipment must be installed to permit maintenance and inspection and to provide for unforeseen emergency shutdown of any unit. If the plant is one of a number of plants feeding into an interconnected system, adequate spare equipment may be available in existing plants so that no additional reserve need be provided. In a number of installations now operating only one boiler unit is installed to serve a single turbine unit. Such cases are, however, the exception.

There is no fixed formula for determining the number of units into which to divide the capacity. Obviously, the smaller the units, the less will be the cost for spare units, but the cost of a small number of large units will be less than the cost of a large number of small units for the same total capacity. Furthermore, with the high degree of reliability characterizing modern units with water cooled furnaces, the number of spare units required is less than was formerly considered necessary. In each case it is necessary to establish the number of spare units required and then determine the size of units which will give the lowest overall cost of plant.

Consideration of Fuel Supply

Next in line for consideration is the fuel burning

and furnace equipment. Fuel for use in the process of steam generation is indeed a variable factor and results in an almost endless variety of plant designs. This variation in fuels in common use, more than any other factor, stands in the way of arriving at anything approaching standardized design.

At the head of the list of fuels is *coal.* But coal alone accounts for a wide range of variations. The Bureau of Mines makes these main classifications: peat, lignite, sub-bituminous, bituminous, semi-bituminous, semi-anthracite, and anthracite. The bituminous range may be further subdivided into coking and non-coking, high ash and low ash content, high fusion temperature of ash and low fusion temperature of ash, high volatile and low volatile and into further subdivisions which have a bearing on the type and dimensions of combustion equipment best adapted to its use for a given capacity. With anthracite the size of the coal ranging through numbers 1, 2, 3, 4 and culm also has an important influence in selecting the stoker equipment.

In addition to coal, fuels available for steam generation include its by-products—coke breeze, coke oven gas, pitch and coal tar. From the petroleum industry there is available fuel oil, acid sludge and petroleum coke; from the wood industry, hogged fuel, tan bark and dry wood refuse; from the sugar industry, bagasse; from the steel industry, blast furnace gas. In recent years natural gas has become an important fuel for steam generation. Garbage and other forms of refuse to a small extent are also in use. In all the above instances, the heat for steam generation is derived directly from the heat of combustion of the fuel. In a considerable number of cases, however, steam is generated from so called waste heat gases from cement kilns, soaking pits and other processes. Boilers utilizing this form of heat are termed "waste heat boilers."

Fuel Burning and Furnace Equipment

For many of the fuels mentioned there is more than one established satisfactory means of combustion. Most of these means are constantly being developed and improved. The past decade has witnessed improvements and new developments which may be termed revolutionary. Much of such development has been the adaptation of old designs to care for the rapid increase in capacity required to serve the large boiler units of today. The outstanding new developments during this period have been pulverized fuel firing and water cooled furnaces, both of which have been in a continuous state of development and have attained a high degree of perfection.

The rate of development has been such that no plant designed as much as five years ago can be wisely used as a pattern for a new undertaking. The proper selection of reliable, adequate combustion equipment, incorporating the full advantage of progress made to date as applying to any set of conditions and fuel supply, is a problem of major importance in the success of the plant. It requires a profound knowledge, a background of vast experience brought up to date by an active participation in present-day practice and good judgment. Where the plant is so situated that it may, at the time or in the future, take advantage of more than one kind of fuel, or of fuels of different characteristics, the proper solution of the problem is correspondingly more important and difficult.

The cost of a selected fuel has little bearing on the selection and design of combustion equipment and furnace. Obviously, it may prove cheaper to use a high grade fuel at a relatively high price which may be burned efficiently with combustion equipment and a furnace design of low cost than to burn a cheap and inferior fuel requiring an expensive equipment to utilize it. Having selected the fuel, however, considerations of good combustion, adequacy, reliability, maintenance, etc., will determine the selection and design of combustion equipment and furnace independent of fuel cost. The burning characteristics and the nature and quantity of the ash content alone will be the principal factors in determining the type of equipment to be used. Maximum and normal load conditions will determine the dimensions. Water cooled furnace walls should be used almost invariably with pulverized fuel firing. With stoker firing and when fuels other than coal are used, consideration of reliability, continuity of service, furnace maintenance, etc., will determine to what extent, if any, water cooling should be used.

The use of water cooling is increasing rapidly with all forms of firing and with all kinds of fuel, particularly as applying to large boilers. Aside from their influence on furnace maintenance, water cooled walls in connection with coal fired, and particularly pulverized coal fired jobs perform an important service by their cooling influence on the furnace gases. Engineers have long since learned that they need have no fear of this influence being so great as to adversely affect combustion. In burning solid fuels and blast furnace gas they have also learned that without this cooling effect, particularly with large units, it becomes next to impossible to cool the furnace gases to such a point at their entrance to the tube nest that trouble will not be encountered from slag formation at this point which ultimately results in reduced capacity or renders the boiler inoperative entirely. To avoid this trouble the gases should enter the tubes at a temperature below the fusion temperature of the ash carried in suspension. This temperature should, and does in good design, become the limiting factor in determining the heat liberation rate per cu. ft. in the furnace.

The more extensive and effective the water cooling surfaces in the furnace construction, the smaller the furnace may be made for a given furnace outlet temperature. At best furnaces for use with coals high in ash of a low fusion temperature must be large, and, conversely, furnaces contemplating the use of coal with a low ash content of high fusion temperature, may be made corres-

pondingly small. In all cases the temperature of the gases entering the boiler tubes should be fixed as a limiting factor and the furnace and cooling surfaces proportioned to obtain it.

Heat Absorbing Equipment

For absorbing the heat from the products of combustion the designer has at his disposal a series of elements including water walls, boiler, superheater, economizer and air heater. Items 1 to 10 inclusive, in addition to the size of units selected, will determine the ultimate temperature to which the outlet gas to the stack should be reduced. The last increment of temperature reduction will require the greatest expenditure for equipment with which to secure it. The designer must assure himself that the value of this last increment in terms of fuel saving must show a profit over the increased fixed charges and increased operating costs of equipment for securing it.

To an engineer of even very small experience it will be obvious that a small plant designed for service eight hours per day for three months per year on coal costing $1 per ton must be built for the minimum cost consistent with reliable service. Efficiency in such a case is of secondary consideration. It will be equally obvious that a large plant for base load operation 24 hr. per day, 365 days per year, and using coal at a cost of $5 per ton, will justify the high cost of equipment required to insure high efficiency, continuity of service, and low labor and maintenance costs.

The two cases cited approach the extreme limits of the range of design. For the conditions cited the decision as to the general type of plant to be adopted is a relatively simple matter. In either case, however, the enthusiasm of the designer may easily lead him to over-reach himself. In the first case his ambition to save money on the cost of the installation may result in inadequacy of design such as to embarrass the operators through inability to consistently obtain the steam output anticipated and required. In the second case his ambition to obtain the last per cent of efficiency may lead him to spend more money than is justified, or to introduce features of complication which seriously jeopardize the continuity of service and also increase maintenance and operating costs to a point which offsets the saving due to the gain in efficiency.

For any given set of conditions the engineer of large experience will know immediately, within narrow limits, the outlet gas temperature for which he can justify equipment. For most cases he will know whether economizers or air heaters or both can be justified. A comparatively short study will enable him to closely approximate the final figure. With the temperature of the gases into the boiler tube bank and the temperature to the stack established, the problem becomes one of proportioning the various elements of the heat absorbing system in such a manner as to give the lowest combination of fixed and operating costs.

If superheated steam is not required the heat absorbing equipment may be limited to a boiler only; or if superheat is required, to a boiler and superheater. In such plants the maximum of simplicity is attained and a reasonable degree of perfection in carrying out the details should insure reliability in operation. The gases will be led direct to a stack of adequate height and diameter and all complications of induced draft fan equipment avoided. The temperature of the gases to the stack will be from 100 to 200 deg. fahr. above the saturation temperature of steam corresponding to the boiler operating pressure or roughly from 500 to 650 deg. fahr.

If the cost of fuel and load conditions justify substantially lower gas temperature, then either an economizer or an air heater or perhaps both must be added. Such a step involves considerable expense and the resultant fuel saving must be substantial to justify the decision. In addition to the economizer or air heater unit, induced draft fan equipment and a more or less elaborate system of gas ducting must be installed. In the case of an air heater, hot air ducting is required. All of these items increase building volume and plant cost and must be justified by the fuel saving. The gross saving will be reduced by the amount of increased operating and maintenance cost. Therefore these factors also must receive consideration in the analysis.

The decision as to whether or not to install economizers or air heaters is often a close one and requires good judgment, experience and careful analysis to arrive at the correct answer. The frequency with which they appear in modern plants, however, is sufficient proof that such equipment merits careful consideration if the most economic solutions of steam plant design problems are to be reached.

The field of the economizer is limited by the feedwater temperature. For every degree that the feedwater temperature is increased in the economizer, the flue gas temperature is reduced about 2.4 deg. If, as is frequently the case, feedwater is delivered to the economizer at a temperature approaching the temperature of saturated steam corresponding to boiler pressure, the capacity of the water for absorbing heat is small and the usefulness of an economizer for reducing flue gas temperature is correspondingly limited. The economizer may or may not be so designed and connected to the boiler that steam formation in the economizer may be tolerated with safety. In the former case the economizer surface may be proportioned to heat the water from the inlet temperature up to boiler steam temperature; it may even generate some steam. In the latter case, the surface should be so limited that the final temperature will be 40 or 50 deg. below steam temperature. To avoid danger from external corrosion, the feed temperature to the economizer should not be less than about 200 deg. fahr. To avoid trouble from internal corrosion the feedwater should be thoroughly deaerated. Having decided to install a unit incorporating boiler, superheater and economizer, the problem becomes one of properly proportioning the

boiler and economizer surface to obtain the final gas temperature for the minimum cost. The proper solution will vary with circumstances and will require analysis based on accurate cost data. This is properly a problem for the manufacturer of the equipment.

In the use of an air heater, a limit is not infrequently placed on the final air temperature. For stoker installations, this limit is usually placed somewhere between 275 and 350 deg. fahr., depending somewhat on the type of stoker and also upon the character of coal to be burned. For pulverized fuel, oil or gas firing the air outlet temperature may be determined entirely from economic considerations. The gas temperature should not be reduced by an air heater to a point much below 300 deg. fahr at the normal rate at which the unit is to operate. This is particularly true if for any considerable amount of time the unit is to operate at a rating greatly below the normal rate. At such times the outlet gas temperature will be considerably below that at normal rate and may result in condensation of sulphuric acid on the surfaces at the cold end of the heater and consequent corrosion of the metal and adherence of solid matter carried in suspension in the flue gases. As in the case of an economizer, the installation of an air heater necessitates the installation of induced draft fans.

Generally, it will prove more economical to provide heat absorption effect in the form of air heaters than with economizers when it may be done without exceeding a fixed limit of air temperature. If the temperature of the feedwater to the unit is low, however, this may not be true. In cases where the feed temperature is high and the limit of final air temperature from the heater is low, and these cases are quite numerous, both economizer and air heater are justified.

Where the heat absorbing unit decided upon includes boiler, superheater, economizer and air heater, the problem of proportioning the units is approached from both ends. With the temperature of the gases entering the boiler tubes established by the furnace design, sufficient boiler heating surface is installed ahead of the superheater to reduce the gas temperature to such a figure as the metal of the superheater will stand. The amount of superheat required will determine the gas temperature at the outlet from the superheater. With the exit gas temperature from the air heater and the inlet air temperature fixed and the limit of outlet air temperature established, the inlet gas temperature to the heater may be calculated. This inlet gas temperature is, of course, the outlet gas temperature from the economizer. The remainder of the problem is to determine what part of the temperature range between outlet from superheater and inlet to air heater shall be absorbed by boiler heating surface and what part by economizer surface to obtain the lowest combined cost.

To assure a proper furnace design and the correct proportioning of the various elements of the heat absorbing assembly for obtaining a predetermined overall result at the lowest cost, comprehensive knowledge is required. The heat transfer rates from gas to water, from gas to steam and from gas to air, through metal partitions by radiation and convection under variable conditions of pressure, temperature and mass flow must be known. Accurate estimates of draft losses must be made. Information concerning physical form and dimensions and cost of equipment must be at hand. Many of the problems involve so many variables that it has been impossible to devise mathematical formulas for their solution. Resort must be continually made to operating and test data obtained from actual installations. Data from installations which are exact duplicates of the design under consideration are seldom available, hence it is necessary to make deductions from data obtained from installations which bear close resemblance. In making such deductions, judgment and experience play an important part.

Draft Equipment

In the consideration of draft equipment, generosity to the point of extravagance in proportioning the forced and induced draft fans is often a real virtue. The ability to supply air to and remove the products of combustion from the furnace places a positive limit on the steam output of the unit. With sufficient draft available, the steam output may be increased to an abnormally high figure for short periods to meet emergency requirements such as may arise from an enforced and unforeseen shutdown of another unit, or through a sudden increase in load arising from trouble experienced at an interconnected plant. In the absence of over-capacity fans, it may be advisable to keep additional boilers in service, or on banked fire. Viewed as auxiliaries, over-capacity fans are expensive, but considering their value as a substitute for spare units, they may, and usually will prove a sound investment.

The fuel burning and furnace equipment must, of course, be capable of supplying and burning fuel in proportion to the air supplied, but the normal equipment will ordinarily respond for short periods of time to the over-rating demand. In any event, this equipment can be designed to provide over-load capacity at small expense. During the period of over-rating, efficiency may be sacrificed, slag formation may gradually accumulate and other undesirable features of operation may be present, but for a short period they may be tolerated without serious injury to the equipment.

Forced draft fans as usually installed are found adequate for anticipated requirements and there is little excuse for their being otherwise. The volume of air required may be easily calculated, and, with a reasonable margin of excess capacity and pressure over and above estimated requirements, the fans should be able to take care of any likely demands. They handle clean air and hence are not subjected to wear. The ducts and passages through which the air is forced stay uniformly clear. The resistance through the burner or grate

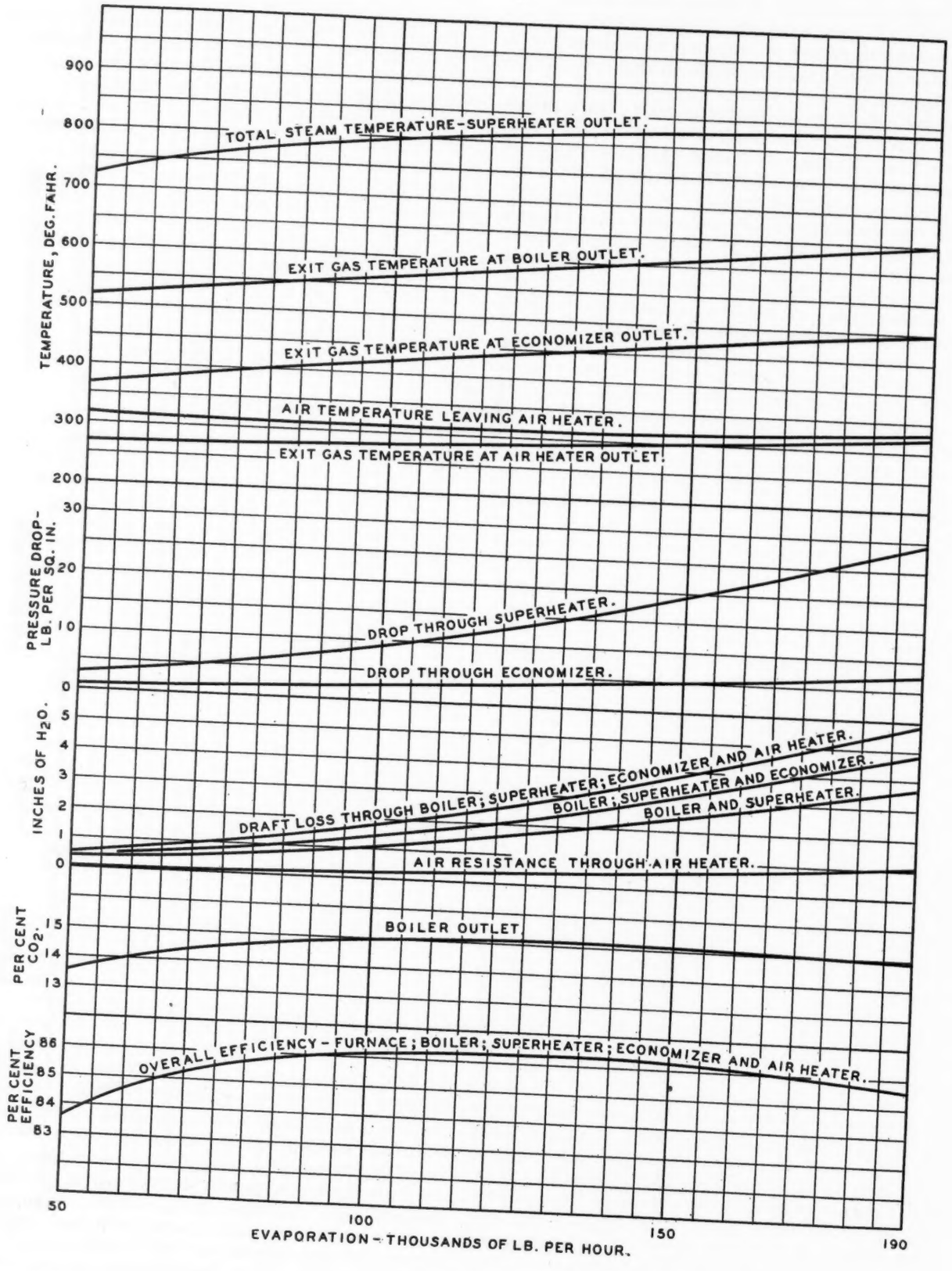

Fig. 1—Typical performance curves based on actual conditions of a proposed installation.

surface and fuel bed should never exceed the maximum estimated. Any leakage into the furnace tends to relieve, rather than over-load, the fan. Hence, in the absence of errors in the original estimate, the fans installed should prove ample at all times to meet the anticipated requirements.

Induced draft fans are frequently found inadequate due to the failure of the designer to properly evaluate the adverse conditions so often encountered in practice. They must handle gases which carry more or less abrasive solids in suspension, causing wear of the blades and running clearances. Some of the solids frequently adhere to the back sides of the fan blades. These factors cause loss in efficiency and capacity. The passages through which the gases are drawn become fouled with ash and hard deposits which may, and normally do, increase the draft resistance. Air leakage in the setting overloads the fans and increases draft resistance. These factors, if not adequately taken into account, invariably result in fan capacity insufficient for the service with consequent difficulty in operation. Generosity in apportioning induced draft fans is seldom over-done. The fans are all too frequently under-size.

Preliminary Design and Estimates

During the progress of design calculations, it is desirable, indeed it is essential, that drawings be made to scale of the assembled equipment in order that the designer may have a proper conception of relative proportions and in order that a practical arrangement of related parts may be worked out. Several such drawings may be, and usually are, necessary before arriving at a design which best meets the requirements of the case in hand. Ofttimes, especially in those instances wherein the equipment must be adapted to fixed space limitations, the final design represents a compromise between what might otherwise be economically desirable and what is necessary to adapt it to the space available. During a preliminary design, all drawings may be, and should be for the sake of economy, very sketchy with the minimum of detail. The final drawing, however, should be complete in its general aspects with sufficient detail shown to make the features of the design readily apparent to those to whom it must be submitted for final approval. It need not, and should not, show construction details. Until the project is approved for construction, the cost of detail construction drawings cannot be justified and they are not necessary.

With the general design of the complete unit established it becomes desirable to make a comprehensive estimate of performance. The curve sheet, Fig. 1, and the heat balance Table 1, are typical. The estimate of efficiency is particularly important since it forms the basis of fuel, air and gas quantities to be handled and draft losses to be provided for; quantities which collectively form the basis for the selection and design of auxiliary equipment.

To complete the case for presentation to those whose duty it becomes to accept or reject the design, an accurate estimate of cost must be made for use either as the basis of an appropriation or as the basis of a sales negotiation.

TABLE I

Actual evaporation (lb. per hr.).....	50,000	100,000	150,000	190,000
Per cent CO_2 at air heater outlet.....	12¾	14¼	14¾	14¼
Temperature gas leaving heater.....	264	281	301	321
Temperature air entering heater.....	80	80	80	80
Lb. dry gas per lb. dry coal.....	13.05	11.80	11.75	11.73
HEAT BALANCE:				
Heat loss in dry stack gas, per cent..	4.90	4.82	5.30	5.77
Heat loss due to moist. in air, per cent	0.12	0.13	0.14	0.16
Heat loss due to moist. and hydrogen in fuel, per cent	5.25	5.28	5.31	5.37
Heat loss due to unconsumed carbon, per cent	1.65	1.04	1.12	1.61
Heat loss due to radiation, per cent..	3.98	2.10	1.40	1.09
Heat loss unaccounted for, per cent..	0.50	0.50	0.50	0.50
Total losses, per cent.....	16.40	13.87	13.77	14.50
Efficiency, per cent	83.6	86.1	86.2	85.5

It not infrequently happens that authorities require several alternate designs for consideration. They may wish to compare a stoker-fired with a pulverized-fuel-fired job, or a unit equipped with economizer against one equipped with an air heater or a cross-drum sectional-header boiler with a multi-drum bent-tube boiler. Such comparisons are always interesting and often useful. They are also expensive.

Detail Design

With the general design of the steam generating unit finally adopted, a design which it may be assumed is eminently suited to the circumstances, the degree of success in its operation becomes a matter of perfection or otherwise of details of design, manufacture and erection of the equipment supplied by the manufacturer to whom the work is entrusted, and finally on the competency of operation. Details of design and manufacture are not the product of any single installation. They are the product of the accumulated experience derived from the entire volume of work of that class which a manufacturer has done. They are forever being changed, improved and finally perfected and standardized. They are the stock in trade of the manufacturing enterprises.

Normally the responsibility of executing a contract in accord with the accepted general design is delegated by the manufacturer to a "contract engineer" who works under the supervision of the engineering department. His function lies in the skillful adaptation of standardized details to the general design already established. It is more than that, however. He must be fully familiar with A.S.M.E. Code requirements and with special local requirements applying to the work in hand and be sure that all details conform thereto. He must do his work in accordance with a carefully laid out program so made as to effectively cooperate with production and erection schedules of his own organization and that of other contractors in a manner essential to completion of the project on schedule time. He becomes the point of contact with the purchaser's engineers and with other contractors contributing to the job; hence he must be tactful, diplomatic and possessed of an intimate knowledge of every detail of the job. He must have good judgment and a background of large experience

on similar work. On him rests the full responsibility for seeing to it that standardized details of construction are properly adapted to the job; that special features of design are brought to and receive the attention of engineering department specialists and that the job progresses in proper time sequence in accordance with program.

Erection and Operation

While it is beyond the scope of this treatise to more than touch upon plant erection and operation, it should be emphasized that much of the merit of a well-conceived general design which has been excellently detailed and manufactured may be ruined by incompetent and hence imperfect erection, and finally a plant which has been excellently conceived, detailed, manufactured and erected, may prove a disappointment through incompetent operation.

The Best Safeguard

Incompetency in any department and in any form is a damaging admission and one seldom made in the absence of convincing proof. It provides the fuel for controversy which prolonged, aggravates the damage to both the guilty and the innocent. The best safeguard against it is a keen appreciation by those in control of the importance, first, of a careful study of the fundamental conditions under which the plant must operate and the requirements which it must fulfill, second, of a properly conceived general design by highly competent engineers, third, of selecting a manufacturer whose equipment has thoroughly proved its merit in actual installations, whose engineering and manufacturing facilities assure a high standard of design details and workmanship, and whose erection staff has earned a reputation for doing a first-class field job, and finally of providing an experienced and competent operating staff.

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Worthington Pump and Machinery Corporation announces the appointment of C. E. Wilson as vice president in charge of industrial relations. For the past nine years Mr. Wilson was general sales manager of the company. He started with Worthington in 1899 as a salesman in the Chicago office, and has been promoted from time to time to steadily increased responsibility in office. His advancement to the post of vice president in charge of industrial relations is further recognition of his unusual energy and capacity. Other appointments by Worthington are: Clarence E. Searle, formerly with Allis-Chalmers Mfg. Co., appointed vice president in charge of sales, Charles N. Barney appointed secretary, treasurer and general counsel; A. L. Prentice is now assistant treasurer. Walter Lehman remains as formerly assistant treasurer in charge of credits. Frank D. Talmage is now assistant secretary. William H. Baumes, for past fourteen years treasurer of the company, retired at the age of 61.

Consolidation Coal Company Reorganizes Sales Department

A reorganization of the sales department of the Consolidation Coal Company has been announced by J. Noble Snider, vice-president in charge of sales, with the following appointments: E. C. Payne is now director of industrial sales with headquarters in New York; J. M. Dougherty is appointed sales manager of the Elkhorn Division with headquarters in Chicago; A. G. Olson has become sales manager of the Pocahontas-New River Division with headquarters in Detroit; C. B. Gleaves is now sales manager of the Millers Creek Division with headquarters in Cincinnati; R. R. Andrews is now sales manager West Virginia Division with headquarters in Cleveland; R. Kinnaird is appointed sales manager of the Maryland Division with headquarters in Baltimore; G. P. Deacon has become sales manager of the Pennsylvania Division with headquarters in New York; A. M. Macleod is named sales manager of the New England Division with headquarters in Boston.

On behalf of the Empire Coal Company, Ltd., the announcement is made that Malcolm McAvity has been elected vice-president of that company with headquarters in Toronto.

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The American Engineering Council at its annual meeting in Washington, elected William S. Lee of Charlotte, N. C., president. Mr. Lee, president of the W. S. Lee Engineering Corporation, is past president of the American Institute of Electrical Engineers, vice-chairman of the Duke Endowment, and consulting engineer of many public utility and industrial enterprises. Other officers elected at the meeting were: L. B. Stillwell and General Richard C. Marshall, Jr., of New York, vice-presidents. Farley Osgood of New York was named treasurer to succeed Dr. Harrison E. Howe of Washington.

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The Furnace Construction Company, recently incorporated have opened operating offices in the Petroleum Tower Building at Dallas, Texas, specializing in the design and building of radial brick chimneys, still and boiler settings, and other firebrick work. Carey E. Coryea, formerly designing engineer for the Rust Engineering Company, is president; W. A. Vandaveer is vice president; F. B. Pierce is secretary and treasurer.

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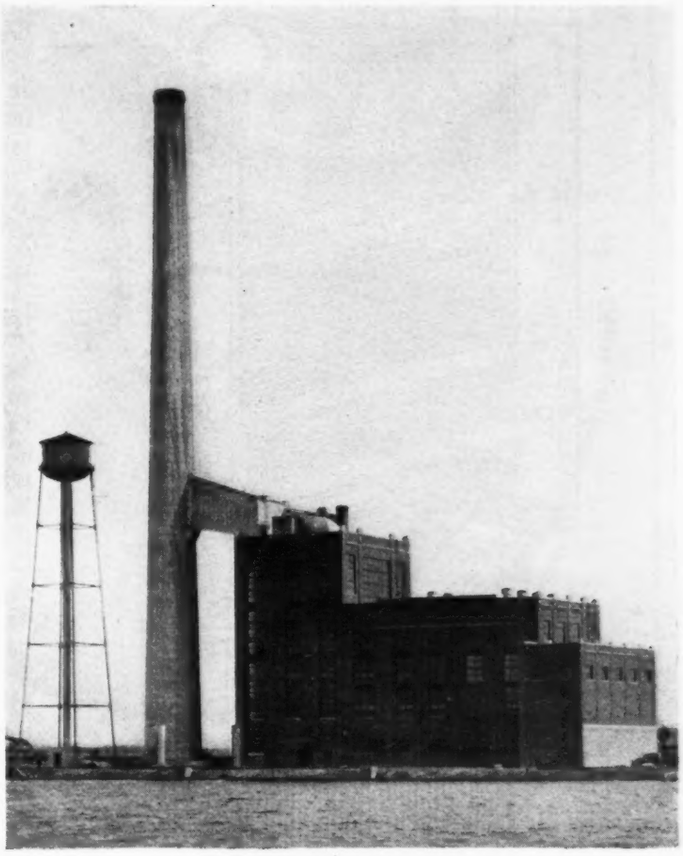
Coppus Engineering Corporation, Worcester, Mass., announce that they have taken over *Annis Air Filters,* a dry type for use on the air intakes of compressors and combustion engines, adding it to their line of airhandling products.

Single Pass Boiler Installation at Duluth Station

By A. H. KRAUSS
Engineering Department
Electric Bond and Share Company



The steam generating unit described in this article is noteworthy for several reasons, first because it is of the single pass design with no baffles in the boiler, second because of its high factor of availability as indicated by the fact of its being relied upon exclusively to furnish steam for a 20,000 kw. turbine-generator, third because of its flexibility in load pickup and range of rating, and fourth because of its excellent performance as evidenced by the accompanying operating data. The author gives a detailed description of the plant and its operation.

THE Duluth Steam Electric Station of the Minnesota Power & Light Company, which was recently placed in operation, was designed primarily as a standby station for its hydro electric system. With this in view and in order to reduce building costs and minimize both operating and maintenance expenses but a single turbine and boiler were installed.

The station is built on piles and is situated on ground reclaimed from the bay by filling in. Both the turbine room and boiler room basements are on the same elevation which corresponds to the outside ground level. The design of the station is in accordance with the most modern practice throughout. The fuel used is pulverized bituminous coal.

The turbo-generator is a 20,000 kw., 0.8 power factor (normal rating), 1800 r.p.m., 13,800 volt, 60 cycle, 14 stage, single cylinder General Electric unit designed for steam pressure and temperature of 400 lb. per sq. in. gage and 750 deg. fahr. at the throttle and 1 in. Hg. normal back pressure. Feedwater is heated on the regenerative cycle by steam bled from the turbine at three stages. All boiler feed make-up water is evaporated.

The boiler room containing the coal handling system, storage bunkers, pulverizers and boiler itself is 58 ft. long by 70 ft. wide by 114 ft. high and is located along one end of the building.

Coal is delivered to the plant by rail in 50-ton flat bottom cars which are unloaded at present by means of a grab-bucket locomotive crane. This crane elevates the coal to a hopper from which it is fed by a reciprocating feeder to a crusher. The crushed coal is then transported to the top of the boiler room by a V-bucket-type conveyor and distributed to the coal bunkers by a belt-type cross conveyor. These bunkers are located in front of the boiler over the raw coal feeders. The coal handling system has a design capacity of 75 tons per hour and the coal bunkers have a capacity of approximately 300 tons.

There are three Hardinge conical ball pulverizers installed each having a design capacity of 6 tons per hr. of coal containing 10 per cent moisture and pulverizing to a fineness of 99 per cent through 50 mesh and 70 per cent through 200 mesh. Coal is fed by gravity from the bunkers to the coal feeders. There is one feeder for each pulverizer. These feeders are of the revolving table and shear type and are equipped with Reeves variable speed drives. The feeders are located on the firing floor and the pulverizers are set below them in the basement.

The coal is dried in the pulverizers by means of heated air furnished by a tubular steam air heater designed to heat the primary air to 300 deg. fahr.

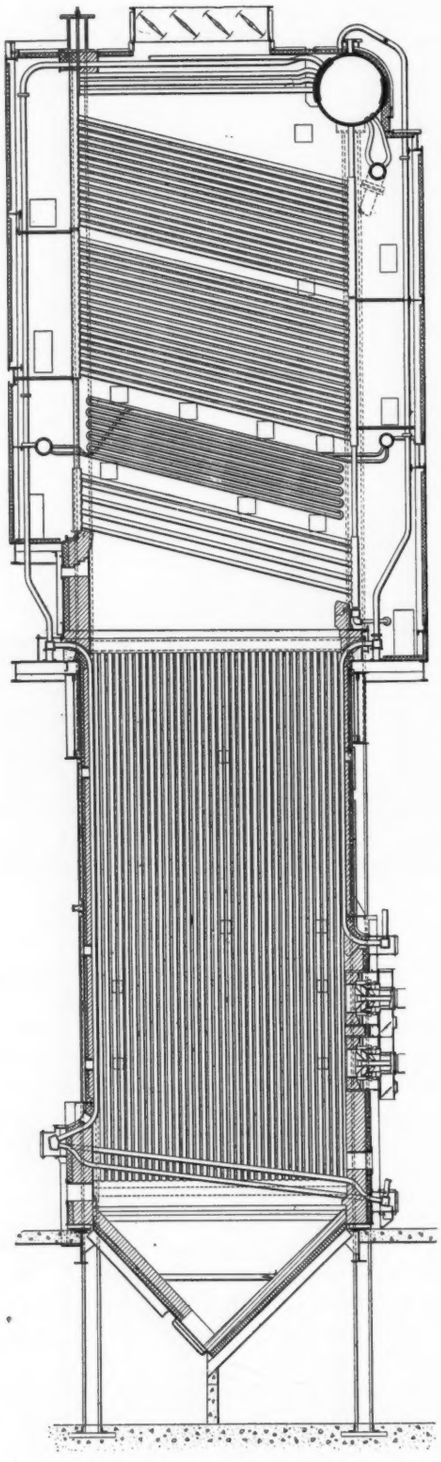


Fig. 1—Sectional elevation of unit.

This air, which is used as primary air, and the powdered coal are drawn through the pulverizers and then discharged to the burners by means of exhauster fans which are also located on the firing floor.

The boiler unit comprising boiler, water-cooled furnace, and burners was furnished by Combustion Engineering Corporation. The boiler itself because of its unique design is of considerable interest. It is designed for a steam pressure of 485 lb. per sq. in. gage with a single gas pass without baffles and is of the Walsh and Weidner sectional header, straight-tube, cross-drum type. Fig. 1 shows a sectional view through the unit. The boiler is 38 tubes wide by 40 tubes high and contains 1634, 4-in. outside dia. No. 6 B.w.g. by 21-ft. long boiler tubes giving a total heating surface of 36,550 sq. ft.

The boiler has a single drum 60 in. inside dia. by 29 ft. long with a shell thickness of 1 27/32 in.

The burning equipment consists of six Lopulco type D burners for horizontal firing. Two burners are fed from each pulverizer. Secondary air is admitted through ports around the burners and is supplied by a forced draft fan equipped with a variable speed motor having a maximum capacity of 120,000 c.f.m. against 5 in. water static pressure when handling air at 100 deg. fahr. This fan is located in front of the boiler at an elevation above the firing floor and is provided with dampers for drawing air either from outside or inside the boiler room. Each burner has a minimum coal-feeding capacity of 1200 lb. per hr. and a maximum capacity of 6000 lb. per hr.

The flue gases discharge from the boiler to a reinforced concrete stack which is located adjacent the boiler room and is 340 ft. high above its base. The gases from the boiler enter the stack 125 ft. above its base.

All four sides of the furnace are water cooled with fin-tube waterwalls. There are 36 tubes in each side wall and 43 tubes in the uptake and downtake walls, those in the side walls and uptake wall extending from the water screen to the level of the mud-drum and those in the downtake wall from above the burners to the top of the furnace. There is also a double plain-tube water screen installed in the lower part of the furnace above the ash pit. The ash pit is refractory-lined having sloping sides for discharging the ash through oil-operated ash gates into ash cars.

The heating surface of the uptake end wall is 995 sq. ft., the downtake end wall, 580 sq. ft., the two side walls, 1855 sq. ft. and the water screen 830 sq. ft., making a total water wall heating surface of 4260 sq. ft.

The furnace volume is 18,500 cu. ft., the width of furnace at the boiler tubes being 22 ft. 5 in., its depth front to rear, 18 ft. 9⅜ in. and its height from center of water screen to center of boiler slag screen, approximately 44 ft.

A multiple-loop, bare tube, single pass, interdeck Foster Wheeler superheater of 7300 sq. ft. of heating surface is installed above the fifth row of boiler tubes. This superheater is designed for a maximum steam temperature of 763 deg. fahr.

The boiler is guaranteed for a continuous output of 300,000 lb. of steam per hr. and a peak capacity of 325,000 lb. of steam per hr. The latter capacity

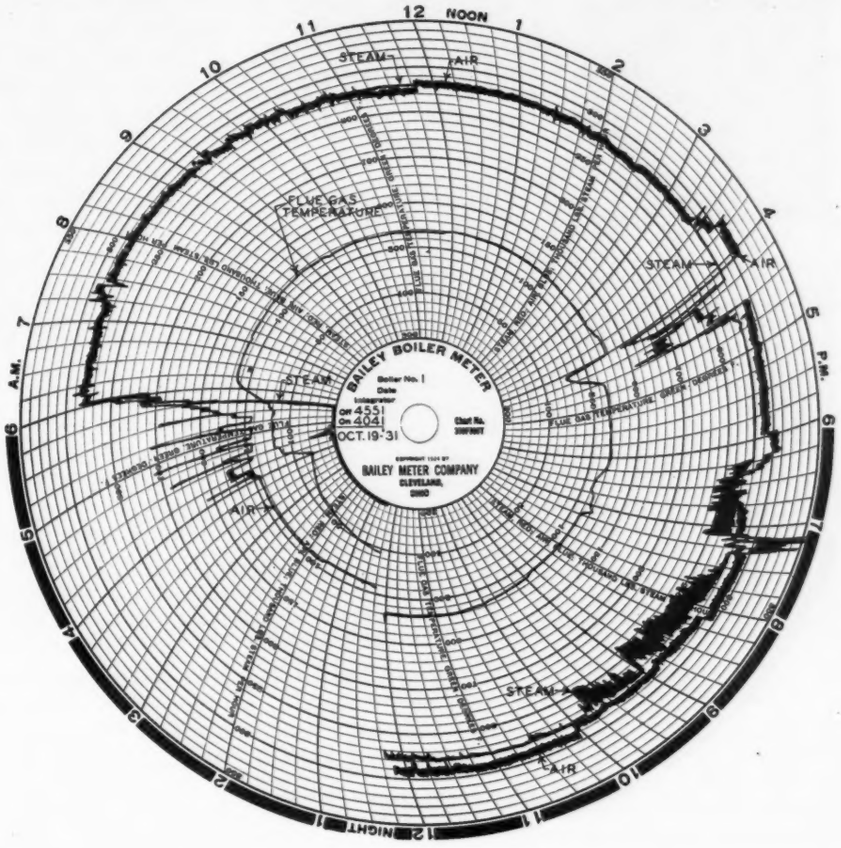
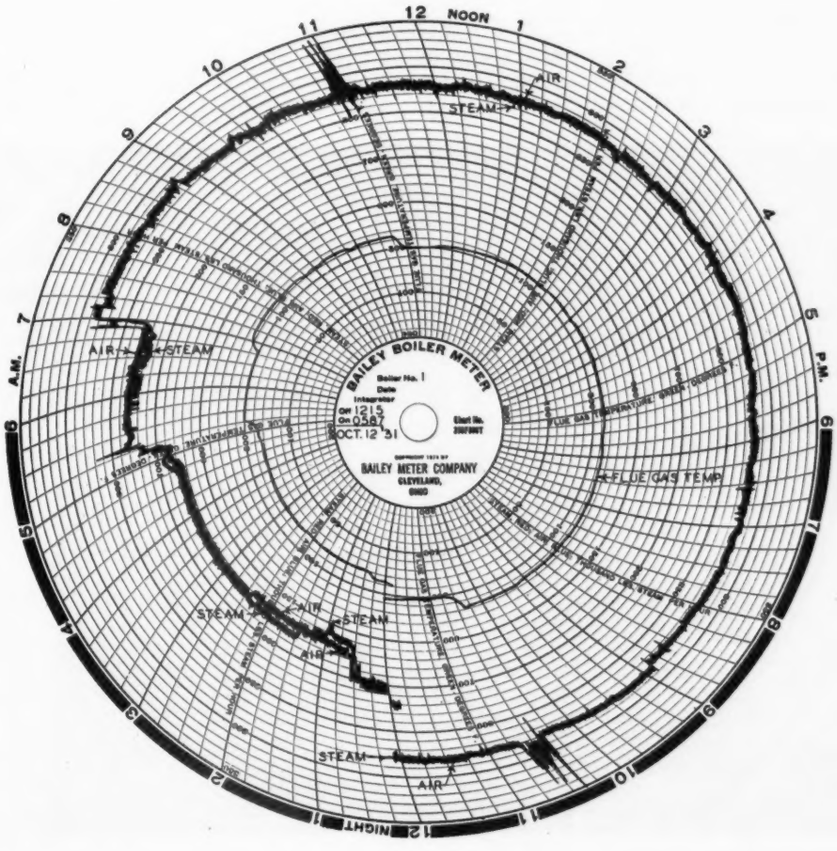


Fig. 2—Typical operating charts showing steam and air flow and flue gas temperature.



Note load pickup on chart above from approximately 3000 to 275,000 lb. of steam per hr. in about 20 min.

corresponds to a boiler output of 349 million B.t.u. per hr., at which rating the heat in the fuel fired

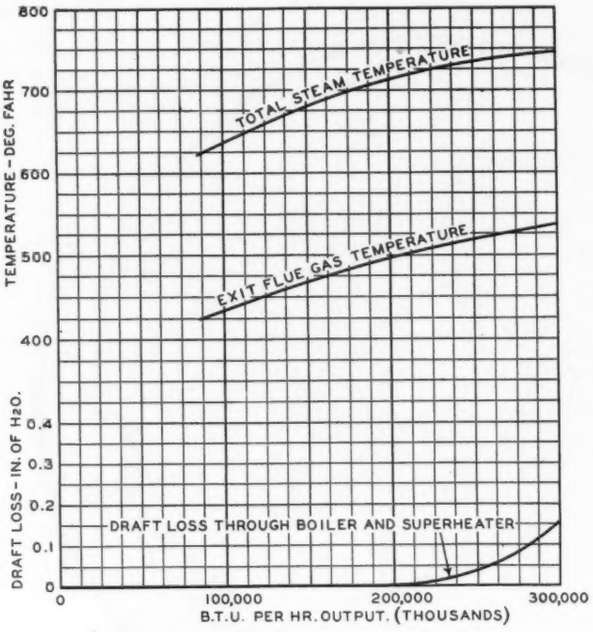


Fig. 3—Chart showing typical performance.

corresponds to a release in the furnace of 24,500 B.t.u. per cu. ft. per hr.

The superheater and several water wall headers are located in vestibules extending along the ends of the boiler. These vestibules not only tend to reduce fluctuations in header temperatures to a minimum but also reduce the danger from overheating by exposure to hot gases. These vestibules also furnish easy access to handholes on boiler headers and obviously offer practical advantages for accessibility and joint maintenance. The method of insulating the water wall headers is also of interest. These are enclosed in insulated boxes with easily removed covers thus facilitating inspection and repairs.

On the sides of the boiler outlet damper, there are located two hinged explosion dampers. These dampers act as a by-pass around the main boiler damper and relieve any excess pressure which may develop in the boiler setting. With this arrangement, in the event of an explosion in the boiler furnace, the objectionable smoke and soot is not released into the building as it is where explosion doors are located in the sides of the boiler.

The boiler feed is controlled by two Stets feedwater regulators one at each end of the boiler drum. Swartwout constant, excess-pressure valves maintain a constant differential pressure across the regulators.

The boiler is under manual control except for the furnace draft which can be automatically regulated by means of a Carrick automatic, electrically-operated furnace regulator. Instruments and control buttons for operating the boiler and for guiding the boiler operators toward obtaining maximum combustion efficiency are located on the firing floor. The individual boiler control panel is equipped with boiler pressure gage; multipointer gage showing furnace draft, stack draft, uptake draft, forced draft fan discharge pressure and wind box pressure; boiler meter equipped with indicating, recording and integrating steam flow and air flow elements, and flue gas temperature recording element; water level recorder; superheated steam temperature recorder; push button controls for forced draft fan outlet and boiler exit dampers;

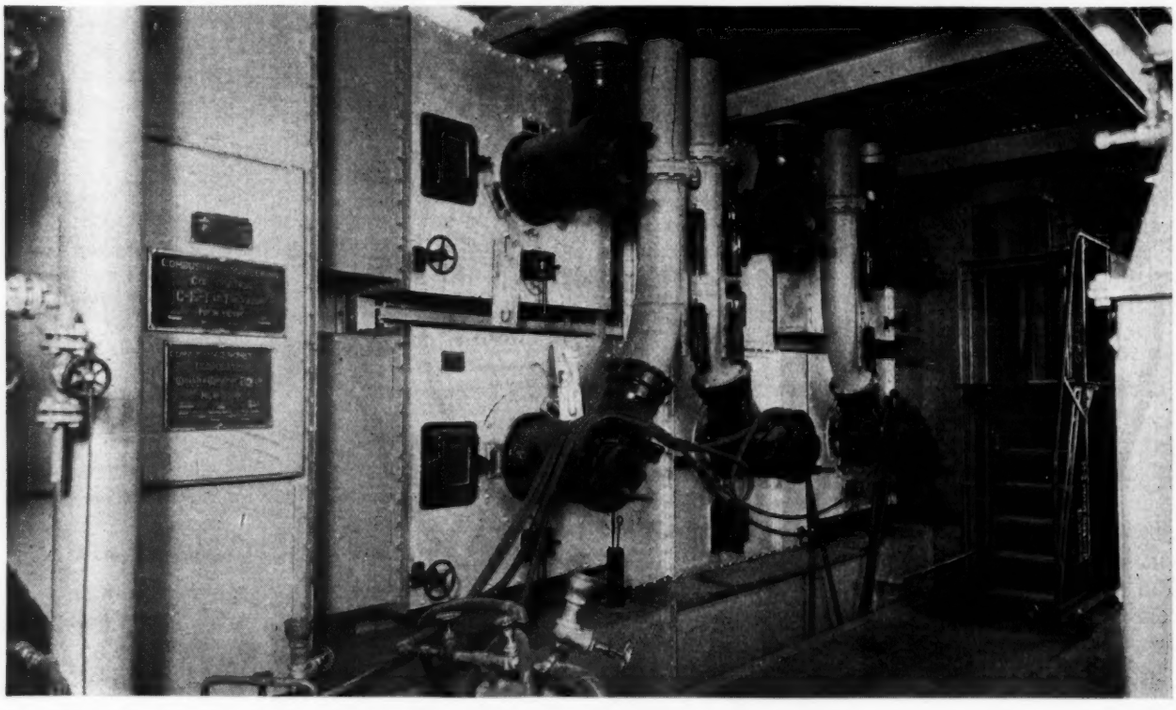


Fig. 4—Firing floor showing pulverized fuel burners.

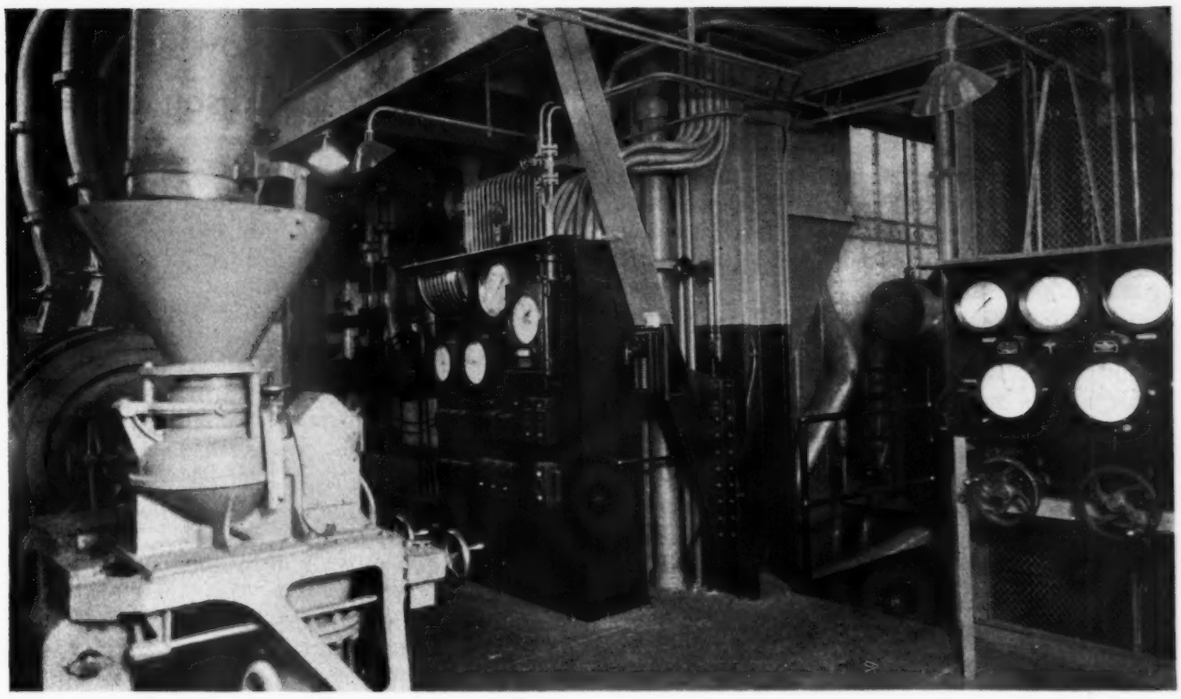


Fig. 5—Firing floor showing individual and master boiler control boards, coal feeder and exhauster fans.

speed controlling push buttons for forced draft fan, and start and stop push buttons for the mill exhausters and feeders. On the master boiler room control board are mounted a clock, boiler blow-off temperature recorder, and boiler feed temperature and pressure recorder. A master pilot gage and a station load indicator are mounted on the wall at the end of the firing aisle. The forced draft fan discharge and boiler exit dampers can also be operated by hand from the firing floor. There are also individual pressure gages installed in the burner piping and windboxes. A venturi meter indicating, recording and integrating the boiler feed and an Eclipse smoke indicator are located on the firing floor.

Although the station has been in operation only a short time, sufficient operating experience and data have been obtained to check the operating characteristics and ease of handling of the boiler.

In starting up from "cold" the forced draft fan is started and operated at low speed and the usual operations of filling the boiler, opening stack damper, etc., are performed. Starting torches utilizing compressed air and distillate are then lighted in two burners which are fed from the same pulverizer. The exhauster on the pulverizer to these two burners is then started drawing air directly from the boiler room until after the pulverizer and its coal feeder have been started at which time the air is drawn through the air heater and pulverizer. The boiler and furnace unit is thus gradually brought up to about 400 lb. pressure at a low combustion rate, the time required being approximately two hours. The other two mills and burners are not cut in until sufficient load is carried on the turbine to demand their use. In bringing the boiler up to pressure and picking up load there is an appreciable rise in water level in the boiler drum. This is handled by starting with the water in the lower part of the gage glass and opening the blow-offs before the water rises too high. Approximately 15 to 16 in. of water in the drum are thus blown down in bringing the boiler up to full load.

As soon as the steam pressure is up, the turbine is started rolling. Due to the minimum capacity of the burners it is necessary to cut off the fire and the steam pressure is allowed to drop down to 350 lb. after which the boiler is again fired up. This is done intermittently at the lowest practical combustion rate for the period during which the turbine is being warmed up. During this period it takes approximately 15 minutes for the pressure to drop from 400 lb. to 350 lb. and about five minutes to bring the pressure back up again.

As soon as the turbine is on the line, the machine can be loaded and brought up to maximum capacity as quickly as additional pulverizing equipment can be started up. The two charts in Fig. 2 taken from the Bailey boiler meter show typical examples of starting and picking up load on the boiler as well as normal operation. Examination of one of the charts shows that the boiler output was increased from approximately 3000 lb. of steam per hr. to 275,000 lb. per hr. in about 20 min. This time varies somewhat due to the way the switchboard operator picks up the load and the coordination between the latter and the fireman.

Typical performance of the boiler unit is shown in Fig. 3. The curves shown thereon are plotted from the daily station log sheets and are not test results. The lower curve shows the draft loss through the boiler and superheater. The draft loss as shown at the various ratings represents the actual differences in readings, at points of measure-

ments of draft gages installed at the top of the furnace and the top of the horizontal circulator tubes at the boiler exit, and no correction has been made for stack effect in the boiler setting. The curve shows that the draft loss is exceedingly low and that for ratings up to 200 million B.t.u. per hr. output the stack effect of the unit itself is sufficient for operating without the aid of stack draft, it being necessary however to use forced draft to overcome burner resistance at this rating.

The center curve shows the exit flue gas temperature from the boiler and the upper the total steam temperature at the superheater outlet. The excess air at the boiler exit damper is approximately 22 per cent.

The combustion is excellent. No trouble is experienced from slag either on the heating surfaces or in the ash pit even though a variety of bituminous coals has been burned ranging from low volatile Pocahontas to high volotile Pittsburgh coals.

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The Kron Company is the name adopted by the former American Kron Scale Company which recently was reorganized. The plant, which produces heavy duty automatic dial scales, has been moved from New York to Bridgeport, Connecticut, where larger and more adaptable space is available. The company resolved to reorganize in order to provide new capital for use in broadening its activities and lines of manufacture. Richard F. Straw, resigned as sales manager of the Wright Manufacturing Company to become president of the new organization. The other officers are: F. W. DeFoe, vice president and H. C. Stevenson, secretary and treasurer. George A. Nichols resigned as New York manager of the Wright Manufacturing Company to become an executive of The Kron Company. The Board of Directors consists of Ernst Ohnell, Chairman, T. A. Yawkey, F. W. DeFoe, Richard F. Straw and H. C. Stevenson.

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Mercon Regulator Company, Chicago, Ill., announces the appointment of R. E. Chase & Co., of Tacoma, Wash., as its representative for the states of Washington, Oregon and Idaho.

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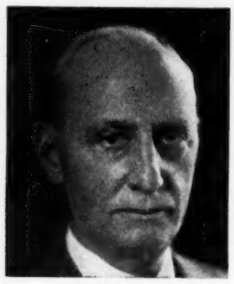
Badenhausen Corporation of Cornwells Heights, Pa., announces the following elections of officials and board of directors: president and director, F. H. Daniels; vice-president and director, James W. Armour; secretary-treasurer and director, Willam N. Way; assistant-treasurer and director, E. G. Stoler; director, David K. Beach. John Phillips Badenhausen has severed his official connection with the corporation. Messrs. Daniels, Armour and Beach are also officials of the Riley Stoker Corporation of Worcester, Mass.

FRANK W. SMITH Now President of the New York Edison System



Bruno & Stoller, Inc.

THE New York Edison Company announces the election of Frank W. Smith as President of that Company and of the United Electric Light and Power Company, to succeed Matthew S. Sloan, resigned. Mr. Smith also is Chairman of the Board of Directors of the New York and Queens Electric Light and Power Company and President of the Brush Electric Illuminating Company of New York.

Mr. Smith has had a continuous connection with his company for fifty-two years, entering the service of the United States Illuminating Company (now the United Electric Light and Power Company) in 1880.

In 1891 he was made Assistant Auditor of the Company. After holding various offices of increasing importance, Mr. Smith, in 1905, was elected Secretary of the United Electric Light and Power Company. In 1912 he was made Vice-President and in 1916 was appointed General Manager.

A year ago Mr. Smith was elected Vice-President of the New York Edison Company. He has been actively connected with the affairs of the National Electric Light Association for many years, becoming president of the Association in 1922. He is a member of the American Institute of Electrical Engineers, Electrical Association of New York, The New York Electrical Society, Engineers' Club, Hollow Brook Country Club and other technical and general organizations.

Mr. Smith enjoys the confidence and friendship of his many business associates as well as of the rank and file of employees in the electrical business of New York City.

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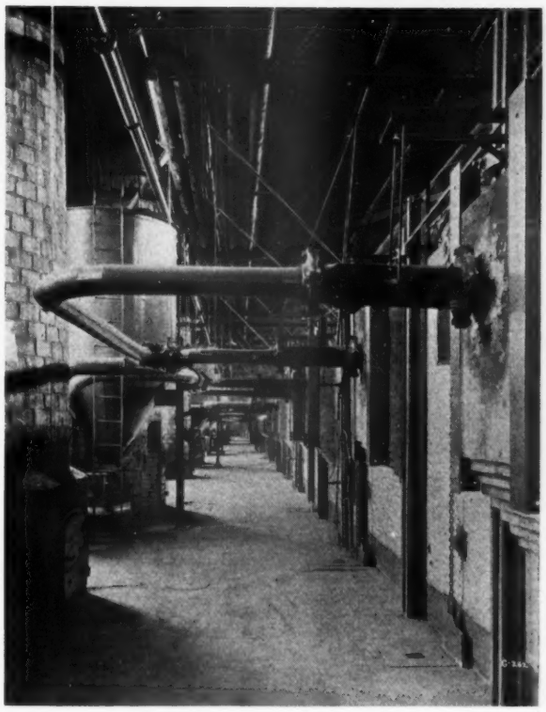
The New York Edison Company announces the following appointments: added to the executive committee were Charles E. Mitchell, chairman of the board of the National City Bank, and George Whitney, member of the firm of J. P. Morgan & Company; elected vice-presidents of the United Electric Light and Power Company and of The New York Edison Company,—R. H. Tapscott, electrical engineer of The New York Edison Company and Arthur H. Kehoe, electrical engineer of the United Company. W. H. T. Jones and Edward J. Tierney were named assistant treasurers and Edward T. Roche was made an assistant secretary. John C. Carroll of United was appointed treasurer, succeeding John C. Moore, who retires after nearly 40 years of service.

Combustion Equipment Revamping in Modern Production Plant Proves Profitable

By FRANK S. O'NEIL
General Manager, Ewart Plant
Link-Belt Company
Indianapolis, Ind.



Battery of 13 malleable iron annealing ovens fired with pulverized coal in plant of Link-Belt Company, Indianapolis, Indiana.

This article describes the operation of a pulverized fuel system in a modern foundry where pulverized fuel is used for firing, melting furnaces, annealing ovens and steam boilers. The installation has effected considerable savings and has greatly improved operating results. The functioning of the automatic control system is described in detail.

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WHEN the first oven was fired on April 3, 1931, a modern installation of pulverized coal equipment, engineered to fit the peculiar requirements of a production malleable and Promal foundry, was put into operation at the Ewart Works of Link-Belt Company, Indianapolis, Indiana.

Since that time this complete pulverized coal system for firing the malleable iron and Promal furnaces, annealing ovens and boilers, has proved to be very successful and profitable from the standpoint of better production and cost savings.

Although the operation of the system, installed by the Whiting Corporation, Harvey, Illinois, has been intermittent, due to production requirements of the foundry, some description of its operation and layout may be interesting to the reader.

The malleable foundry at Ewart Works has been in use some 17 years, all of the equipment being hand fired. The products have been very high quality chain castings and industrial castings produced, under what we believe to be the latest foundry practice. To meet our requirements the pulverized coal engineers had a high mark to shoot at but with the cooperation of the two organizations, an installation that controls the various elements in the iron and produces very uniform metal from day to day has been evolved. Very substantial savings in labor, refractories, and iron have been effected and the elimination of smoke makes a decided improvement in working conditions.

The first thing that strikes the visitor is the cleanliness and orderliness of the plant, so typical of modern pulverized coal equipment. From the time of its receipt at the plant until it enters the furnace, the coal is automatically handled, the entire system being absolutely dust-tight. All smoke from opening the fire doors is therefore eliminated.

The accompanying illustrations show the principal equipment and indicate the general arrangement. The fact that all of the furnaces, ovens and boilers were already in use, most of them for a considerable period of time, illustrates the ease of applying pulverized coal to old equipment. Few changes were required and the entire system was put in without interruption to plant schedules.

The system as it now stands consists of crushing and pulverizing equipment, conveying lines, storage hoppers and feeding and firing units for the different furnaces. The capacity of the preparation plant is sufficient to permit adding more ovens or furnaces as production increases. The

system is so designed and arranged that future additions can be made without disturbing the main system or losing any part of the present equipment.

Let us follow a lump of coal from its receipt at the plant to the firing line. The incoming car is spotted over a receiving hopper underneath the switch track and the coal dropped into this hopper. From there an inclined steel apron conveyor carries it to the Link-Belt double-roll crusher in the preparation building alongside the track. This crusher has a capacity of 36 tons per hr. The apron conveyor is equipped with a magnetic head pulley to take out the tramp iron before coal enters the crusher. The crushed coal, reduced to 1¼ in. lumps, drops into a bucket elevator, which carries it to a concrete storage silo of 700 tons capacity. This type of storage silo has been used in all of the latest installations.

From the silo the coal is fed by a gravity chute into a Raymond kiln roller mill, where it is pulverized and dried at the same time. With the kiln mill no separate dryer is required, thereby reducing the cost of the preparation equipment and subsequent operation. The air for drying the coal in the pulverizer is heated in a separate oil-fired heater, and enters the pulverizer at 300 deg. fahr. This gives a temperature of from 110 to 150 deg. fahr. in the pulverized coal discharge pipe. Automatic control is provided so that the heater is shut off when the air reaches the desired maximum temperature. This can be regulated to suit conditions. The excess air used for drying passes through a cyclone collector at the top of the pulverizer for cleaning and is discharged outside of the building. The degree of fineness is under perfect control and on account of using air separation the desired fineness is easily maintained. The dry pulverized coal is discharged into a 60-ton capacity storage hopper Fig. 1, and is now ready for distribution to the various furnaces and ovens.

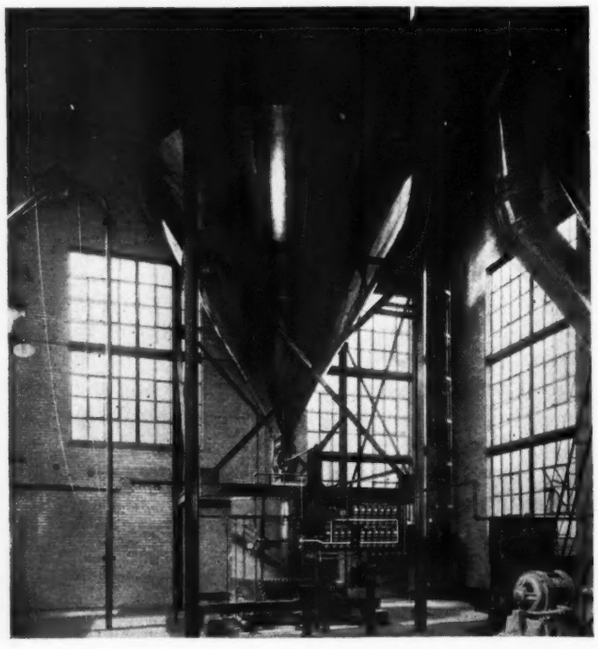

Fig. 1—Corner of pulverizing plant showing 60-ton pulverized coal storage bin, 5-ton weighing tank, signal board and 4 in. dia. pneumatic conveying line.

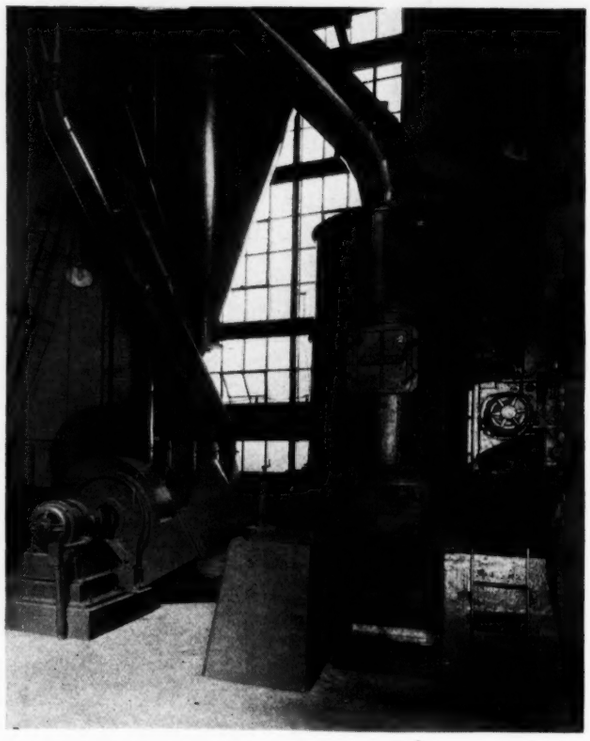

Fig. 2—Interior of pulverizing plant showing mill on right and signal board used on pneumatic conveying system on left.

This distribution is made by means of a pneumatic conveying system controlled from a central signal board at the main storage hopper. The coal is conveyed through 4-in. standard steel pipe, direct to the various units to be fired. Before dispatching it to the furnaces, the coal is fed into a 5-ton weighing tank mounted on a scale with weightograph attachment, Fig. 1, which accurately records the amount of fuel used.

A dust collecting line is installed, parallel to the conveying line, which removes the fine coal dust carried off by the cyclone located at one of the furnaces.

To illustrate the automatic operation of this system, assume that coal is needed for furnace No. 1. The furnace attendant pushes an electric button and immediately a colored light appears on the central signal board, telling the operator that coal is desired at No. 1 furnace. The operator then presses a button which releases the switching valve at No. 1 furnace and allows the furnace attendant to open the valve by pulling the pendant chain. Automatically a different colored light flashes on the central control board, informing the operator that the valve at No. 1 is open, ready to take coal from the main feed line. The coal is conveyed by compressed air (15 to 35 lb. pressure) and as soon as it reaches a predetermined level in the storage bin at the furnace, an automatic limiting device closes the valve and stops the coal flow. At the same time a third

light flashes on at the central control board to tell the operator that No. 1 furnace has been supplied.

The system is so interlocked that the switching valves for drawing coal from the main line cannot be opened by the pendant chain until the operator at the central control board has released the valve. The safety manhole cover on each individual storage hopper is also interlocked so that no coal can be conveyed into the hopper if the manhole cover is not properly sealed. The entire transport system is worked out for automatic operation and perfect control, avoiding any possibility of overfilling the hoppers or spilling the coal. Everything is absolutely safe and dust-tight. The cost of transporting coal by compressed air averages about 6 cents a ton.

Returning to No. 1 furnace, we find the hopper filled with coal, ready for operation. A screw feeder attached to the bottom of the hopper feeds the coal at the desired rate, positively controlled by a Link-Belt P.I.V. Variable Speed Transmission for combustion. As the pulverized coal enters the exhauster it is picked up by the air stream and delivered to the burner. Here the air and coal, in proper proportions, are thoroughly mixed and blown into the furnace. Valves are provided that give very close adjustment of air and permit perfect control of combustion. This completes the cycle of operation.

But a very small amount of ash is formed when burning pulverized coal. In the case of the melting furnaces, this goes off with the slag and other refuse; in the boilers it is deposited on the bottom of the furnace and has to be removed occasionally the same as with hand firing, only not so often.

Three different styles of burners are used. The melting furnaces are all equipped with stream line

Fig. 3—15-ton capacity malleable iron melting furnace fired with pulverized coal.

burners, which give a low velocity flame required for metallurgical melting. The annealing ovens are all equipped with high-low velocity burners which give a flame of variable length—a short flame for starting and long flame for bringing up the front of the oven and holding an even temperature. Each of the three 20-ton ovens has one burner; the ten 35-ton ovens are equipped with two burners each.

The three 200-hp. h.r.t. boilers used for heating the entire plant are equipped with the turbulent type of burner, which gives a short, hot turbulent flame suitable for this class of work. The secondary air for combustion is controlled by an air gate with atmospheric intake.

Savings

Aside from the convenience of automatic, perfectly-controlled operation, this system is making very definite savings in both labor and materials. On the annealing ovens, for instance, several hours have been cut off the cycle of operation. Because

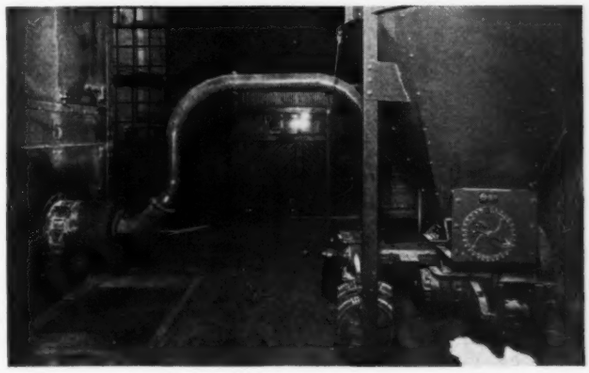

Fig. 4—Two 150 hp. h.r.t. boilers are also fired with pulverized coal. This view of one boiler unit shows 3-ton bin, screw feeder, exhauster and turbulent flame burner.

the temperature throughout the entire oven is uniform, castings can be placed in any part regardless of size and come out thoroughly annealed. There is a very marked saving in fuel cost. Formerly, with hand firing, these same ovens required 752 lb. of fuel per ton of castings annealed; now with pulverized coal, the consumption has been brought down to an average of 500 lb. per ton.

A number of economies have been effected on the melting furnaces. The elimination of hand firemen is a big item. A higher percentage of good castings and more uniform analysis of iron are an important result. Very hot fluid iron is obtained, 2700 deg. fahr. and above, at the spout. It is also found that the iron retains its temperature in the ladle longer than with hand firing. 90 per cent of the heats so far have come out minus or plus five points in carbon. Less oxidation and less wear on the furnace lining are other items; also a better ratio of coal to iron.

On the boilers, which are operated only for heating the plant, there is the double saving of labor and fuel, and the advantage of a more easily controlled heating plant.

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The Dampney Company of America announces that Mr. Clarence J. Hunter, formerly Philadelphia District Manager and then General Sales Manager, has been elected Vice President and will be in charge of sales.

History and Developments in the Art of Welding Ferrous Metals

PART II

By A. J. MOSES,
Hedges-Walsh-Weidner Co.
Chattanooga, Tenn.

Part II of this article continues the discussion of forge welding processes. Roll welding and resistance welding, which the author classifies as being in the forge welding category, are reviewed historically, their respective techniques described and their applications, advantages and disadvantages indicated. The several forms of resistance welding, i.e., butt welding, spot welding and flash welding are included in this discussion. The latter part of the article begins the discussion of fusion welding the history of which is said to date back to the time of the Pharaohs. Thermit welding which the author classifies as a modern extension of the old cast weld idea is the only process in current use described in this installment. The other forms of fusion welding will be considered in the two following articles which will complete the series.

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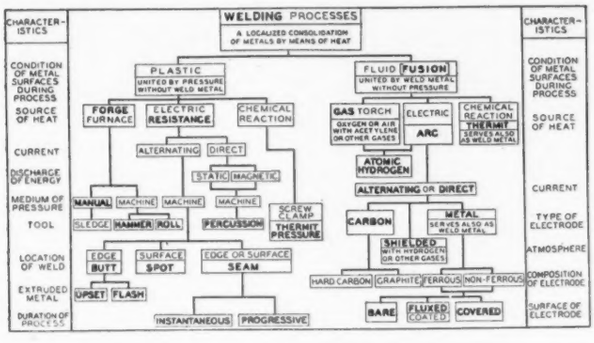
Roll Welding: Closely allied to the hammer-welding process described in Part I of this article, are the hydraulic and roll welding methods. Hydraulic application will not be discussed because of its marked similarity to hammer welding and because its function will be covered in the discussion of resistance welding. Roll welding deserves some attention because of its special application to the manufacture of pipe. Lap welded pipe is made by this method, the operation being essentially as follows. Long narrow plates called the skelp, are prepared by cutting to the proper width and scarfing or beveling the long edges. These are then heated in a furnace and drawn through a bell die which gives them the proper curvature and the proper overlappage of the scarfed edges. The skelp, now ready for welding, is charged back into the furnace and brought to a white heat. At that temperature they are withdrawn and fed between the welding rolls. The peripheries of the two welding rolls are grooved so that at the tangent point they reduce the overskelp to the proper diameter. The welding rolls feed the pipe over a mandril, the extremity of which is bullet like and of a diameter equal to the required inside diameter of the pipe. The head of this mandril is directly between the two rolls. The feeding of the hot skelp over the mandril head and between the reducing rolls affords the necessary pressure for welding and sizing the lapped edges. The welding operation is very rapid. It must be done while the skelp is at a white heat. At that temperature any oxide scale is liquid and drips off. Butt welded pipe is made in a somewhat similar manner, by substituting a bell die for the welding rolls.

The first application of roll welding was probably in the manufacture of wrought iron merchant bar, wherein box piles of muck bars were stacked and roll welded. Welding was one of the first accomplishments of the pioneer rolling mills. Multiple-ply steel plate is produced by this process. Butt and lap welded pipe and tubing were introduced on a large scale early in the last century. At that time all such piping and tubing was made of wrought iron and to this day, there is a large demand for the double refined wrought iron product because of its supposedly better non-corrosive qualities. Butt and lap welded steel tubing can be made very cheaply by this process. This product has a wide variety of uses where the strength of the weld joint is not an important factor.

Roll welding may be credited with some of the advantages and all of the disadvantages of the hammer welding process. It is a much cheaper process but, as with all rolled material, it is considered inferior to the hammered product. It has no competition in the manufacture of merchant bar iron and multiple-ply plate. It is restricted to a rather narrow field as regards sizes and shapes. The quality of the product is not dependent to any large degree upon the individual skill of the operator. The standard of quality obtainable by this process is not so high as that from hammer welding. On the other hand the method is generally restricted to that class of work wherein its properties are ample. Also it is usually applied to inexpen-

sive construction where it is more economical to scrap and replace rejections than to attempt repairs by other welding methods.

Resistance welding: This type of welding is generally regarded as an electric process, but in reality it belongs to the forge welding category.



Classification of principal welding processes.

The actual joining of the material is accomplished by the application of pressure either mechanically, pneumatically or by hydraulics. The pieces to be joined are heated electrically to a welding temperature, but as first introduced and applied, the heat was held below the fusion point. A typical illustration of the resistance process is found in the butt welding of two iron bars, end to end. The two bars are fitted into the copper jaws of two heavy clamps on the welding machine in such a manner that they are in alignment with abutting ends in close contact. The copper jaws are connected to the secondary terminals of a step-down transformer which delivers a very heavy current at a very low voltage for the heating operation. The current required is about 16,000 amperes per sq. in. for iron and 60,000 amperes for copper. The abutted work closes this secondary circuit. The connections to the transformer and the clamping jaws are heavy, and the gripping surface large, so as to prevent overheating of these parts. The closing of the primary switch causes a heavy current to flow across the juncture to be welded. The high electrical resistance at this point quickly raises the temperature of the abutting ends to a white heat. At this temperature the current is cut off, and pressure is applied through the clamps giving compression at the juncture. This compression causes an outflow of the liquid oxide scale from between the juncture, and is so regulated as to effect a forge weld of the unfused ends with some upset around the joint.

Another form of the resistance process is found in spot welding. This method has attained wide employment, in lieu of riveting, in all classes of thin plate fabrication. As its name signifies, this method is used in joining two or more overlaid or overlapped plates, by welding their surfaces together at various spots. The operation is carried out on a welding machine much like a riveting or punching press. The plates with surfaces thoroughly cleaned are inserted between the jaws of the machine and clamped tightly together at one of the desired spots. The clamping dies are copper and are proportioned to the diameter of the desired spot weld. With the pressure maintained, a heavy current is passed through the dies and plates. The resistance at the joint affords the welding heat and an increase in pressure effects the juncture. The pressure is not released until the metal has somewhat cooled. Although spot welding is admirably suitable for many purposes, its reliability can not greatly exceed that of riveting.

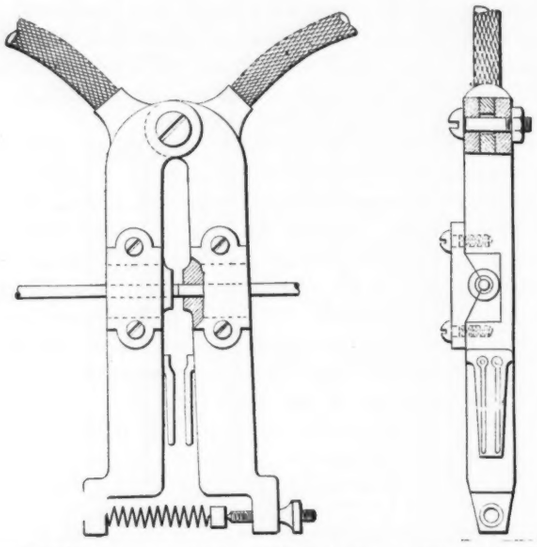
Flash welding is the latest and most promising development of the resistance idea. It partakes of the nature of arc welding, but is in a true sense a pressure weld. While an arc is established between the pieces to be joined, its function is a cleansing one with the attaining of a highly localized welding heat. While a film of fused oxide and metal covers the surfaces, these are excreted by pressure and the eventual joint made between underlying surfaces of unfused metal.

The first successful commercial application of resistance welding is credited to Prof. Elihu Thompson. Some experimental welding of this type had been accomplished by Prescott Joule about 1860. But it was twenty years later when Thompson brought out the first practical welding machine. The first joints obtained by this method were often spongy and burnt due to over heating and improper application of pressure. With accumulated experience, the skill necessary to overcome these objections was soon acquired. Within a few years after its introduction, the Thompson

Heavy duty spot welding machine.

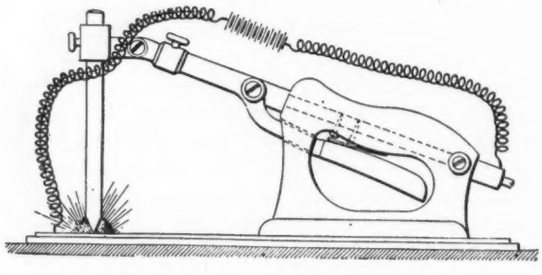
method displaced the older forging process in the production of many stock welds in numerous industries. Also it effected many changes in design involving both methods of manufacture and choice of materials. Special automatic machines were rapidly brought out for the mass production of duplicate articles. At the turn of the last century this method was considered the most reliable welding process available. While there is only scant test data setting forth the true quality of those welds, undoubtedly general experience justified the high esteem in which they were held. The fact that

much of this welding is done automatically leads to more uniformity in production and results. Resistance flash welding is an advancement of late years and is still in its development stage. Its application is increasing and is already well established in the automotive and in the tube and pipe industry.



First practical electric butt welding device, patented by Elihu Thomson, August 10, 1886.

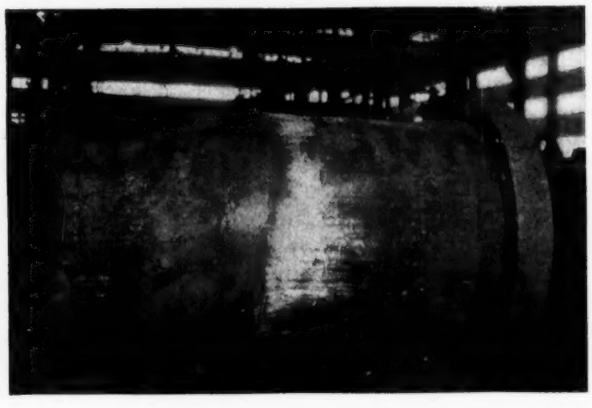
Resistance and resistance flash welding enjoy many advantages over other methods in the continuous welding of duplicate articles. These advantages consist of economy and quality. While the quality of such joints is probably no better than the best obtainable by other forge welding processes, the adaptability of this method to almost fully automatic operation, insures much better average results. With proper technique for a specific job once established, quality in quantity production can be readily obtained. In these processes the heat is under control and highly localized to the juncture where needed. Although it is most efficient in connection with those metals which are plastic through a wide temperature range below the melting point, it gives fairly satisfactory results with many of the metals. It is frequently used in the joining of dissimilar materials. The practical restrictions regarding sizes and shapes are probably greater than those concerning materials. The unit conductivity of the materials and the areas at the juncture must be carefully considered in arriving at the proper technique.



Original Bernardos carbon electrode apparatus.

In the resistance method the efficiency of the transference of skill and intelligence into automatic machines, is approaching its limits. Diminishing improvements in quality but increasing application of this mode of welding is predicted. Some welds being made today approach the ultimate attainable by this process. The modern flash system appears ideal for obtaining parallel clean surfaces for pressure welding. The film of fused metal protects these surfaces and under the welding pressure, washes out all harmful impurities. However the quality of the cleanest, aligned intergranular seams formed in plastic metal under pressure is hardly equal to that of random seams formed during recrystallization of clean fused metal. Much of the above assumes perfect conditions. In practice defects often occur in resistance welding due to overheating, unequal heating, improper application of pressure and imperfect elimination of oxide scale and fused metal which may contain occluded gases.

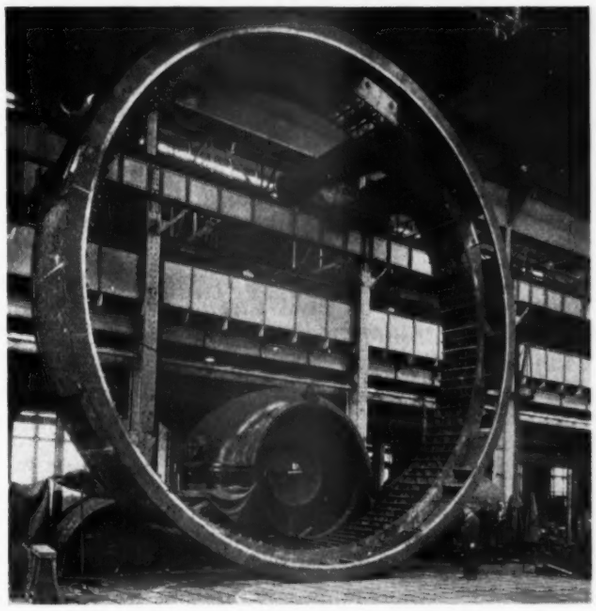
The majority of the defects encountered in this class of welding are probably latent and their nature only determinable by microscopy. Only those of a gross nature could be detected by x-ray examination. Any discoverable defects would have to be repaired by some other method of welding. In most cases wherein this method is employed, such rigid testing and accurate knowledge concerning the true value of the juncture is unnecessary. But in such applications as the longitudinal seams of pressure vessels containing explosive liquids or gases, the knowledge of even incipient defects is of utmost importance. As yet no such application of resistance welding has been made other than in the manufacture of steel pipe in which no heavy plate thicknesses or high stresses are encountered. Its employment in heavy wall vessels is also constrained by the high initial cost of the necessary equipment, the enormous and short time demand for electrical energy, and the small number of such pressure vessels constructed.



30 ton cylinder for hydraulic press repaired by thermit welding. Cost of new casting $7500, delivery time 35 days. Cost of repairs $550, time required 10 days.

Fusion Welding

The process of fusion and uniting metals with or without the introduction of additional material, is now termed, Fusion Welding. In this process



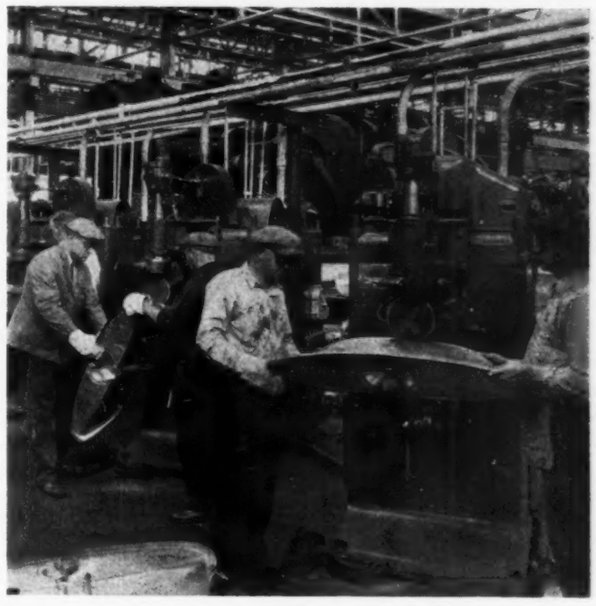
A frame for a forty thousand kilovolt waterwheel generator, 37 ft. in dia. made from steel plates welded together. This has replaced extensive castings.

no pressure is required to effect the juncture. Practically all of the commercial welding methods, other than those previously discussed, belong to this general classification. While this process is hardly as old as forge welding, its use in connection with the metals of low melting points, probably dates back to the time of the Pharaohs. The goldsmiths or jewelers of that time were masters of the art of soldering. Illustrations of early metallurgic operations showing the use of the blowpipe, were found in the ancient paintings of Kourna, Thebes.

Until the latter part of the nineteenth century, this method of joining metals was termed "burning." An old dictionary defines burning as, "Joining metals by melting their adjacent edges, or heating the adjacent edges and running into the intermediate space some molten metal of the same kind." The term, "lead burning," in use today is a survival of this use of the word. The fusion welding of lead was practiced by the Romans in the manufacture of water pipe, before the time of Christ. Also this method has long been in use in the welding of pewter, brass and, later, cast iron. In connection with the latter, cast welding is probably a more descriptive term. The repairing of cast iron articles by this process, was first practiced by the native smiths of India and China. Van Braam, an attache of the Dutch Embassy at Pekin in 1794, made note of this novel way of repairing cast iron pots and kettles. In cast welding this material, an excess of molten metal was used. This excess was poured continuously through the fissure or hole thus bringing the edges of the metal to a semi-fluid condition. The balance of the metal was then caught and allowed to solidify within the fissure.

A modern extension of the cast weld idea is found in the thermit process. Thermit was invented by Dr. Goldschmidt of Essen, Germany, about the year 1900. This invention consisted of the preparation of powdered aluminum with oxide of iron, which mixture is called thermit. On ignition the aluminum in this mixture reduces the oxide to molten steel at a temperature of about 5400 deg. fahr. The reaction is very rapid, taking less than thirty seconds. When used in cast welding this thermit steel, due to its high temperature, thoroughly fuses with the parts to be joined.

In preparation for a large thermit weld, the pieces to be joined are aligned with welding faces parallel and with an intervening gap of about ¾ of an inch. This intervening space is filled with wax. Also a wax "button" or reinforcement is built up around the weld and overlapping the surfaces of the parts to be joined. The wax constitutes a pattern of the desired thermit weld. From the amount of wax used, the required amount of thermit is calculated. Around the immediate section to be welded, a flask is built in which a molding sand of fire clay and silica is tightly rammed. Risers and gates as well as openings for the introduction of pre-heating torches, are arranged in the mold. Gas or oil torches are directed into these ports and the ends to be welded brought to a red heat. This is for the purpose of insuring proper



Seam-welding machines used for welding gasoline tanks.

fusion of the base metal with the added thermit and to prevent the chilling of the first thermit introduced which might cause "cold-shuts." The thermit powder with some admixture of steel turnings is prepared in refractory lined cone crucibles and placed over the mold with tap hole in position

over the pouring gate. When the pre-heating operation is completed, the ports are closed with fire clay and the charge of thermit ignited. A heated bar of iron can be used to set off an auxiliary fuse powder which produces the temperature necessary for the ignition of the powdered aluminum. After the reaction is complete and sufficient time allowed for the slag to rise to the surface, the crucible is tapped and the thermit metal allowed to run into the mold. Provisions are made for taking care of the slag which in volume, is about three times that of the thermit metal. The weld is allowed to cool slowly before tearing down the mold. Also when possible the joint is given a further annealing.

Thermit welding is particularly applicable in the repairing of heavy machine parts, forged or cast steel. By this method such repairs can be effected on the spot without expensive dismantling of the machine. In light section routine work this process is too expensive to compete with others. But its adaptability to heavy section repairs in awkward positions, achieves savings in time which outweigh the cost of the actual welding operation. Its use is practically limited to iron and the mild carbon steels. The skill necessary for the production of strong homogeneous thermit welds is easily acquired. Joints of a tensile strength equal to or exceeding that of the base material, are readily obtained. In ductility such joints show from 10 to 30 per cent elongation in 2 in., depending upon the heat treatment given. In that field of welding where thermit is most suitable, it is often impractical to thoroughly anneal or stress-relieve the completed weld. For this reason, failures sometime occur adjacent to the repaired section. However this loss is not peculiar to the thermit process.

Joints obtained by this method are not without defects. The weld metal is in fact only cast material, and is subject to all the ills of such material. Insufficient pre-heating of the base metal causes a chilling of the first thermit entering the mold and results in imperfect fusion to the base metal and blow-holes within the joint. Premature tapping of the crucible prevents the proper separation of the slag from the thermit steel and leads to slag inclusions and other faulty structures. Failure to make allowance for the shrinkage of the cast metal may result in cracks. If applied to such work as requires the most rigid inspection as to quality, x-ray or radium examination would expose such defects as porosity and cracks. But in case of a rejection an entire section through the defects would have to be removed and re-welded, or, only such defects removed and the metal replaced by other processes.

While thermit welding has been successfully applied to such production as rail welding and the butt welding of pipe ends, it is essentially a repair process. In rail welding it suffers from competition with cheaper methods and in the buttwelding of pipe it is merely used as a heating agent. The process has achieved spectacular results in the repairing of heavy equipment such as broken sternposts, propeller shafts and similar heavy parts.

Symbols and Abbreviations for Mechanics, Structural Engineering, and Testing Materials

The American Standards Association approved at its January meeting the sixth of a series of symbols and abbreviations to become American standards. The symbols for mechanics, structural engineering and testing materials were developed by the Sectional Committee on Scientific and Engineering Symbols and Abbreviations and sponsored by the American Association for the Advancement of Science, American Institute of Electrical Engineers, American Society of Civil Engineers and the Society for the Promotion of Engineering Education.

Copies of this new American Standard are available through the A. S. M. E. Publication Sales Department, 29 West 39th Street, New York, N. Y. at 35 cents a copy.

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Fisher Governor Company, Marshalltown, Iowa, announces the election of Jasper H. Fisher as president. Mr. Fisher has been associated with the company since 1912, and in that 19 year period has served as secretary, president, and for the past two years as chairman of the board of directors. Mr. Fisher succeeds L. W. Browne who resigned as president, an office which he has held for the past two years.

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Timken Roller Bearing Company announces the following appointments: William E. Umstattd, who has been with the Timken organization for 12 years, during the last two years of which he was factory manager, has been made executive vice president. Henry H. Timken, Jr., who has been assistant works manager of the Timken Roller Bearing Co. for the past 2 years, has been made assistant to the president of the Timken Steel & Tube Co., Canton, Ohio.

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Ohio Coal Investigation, Part I. The Engineering Experiment Station of the Ohio State University has just issued as bulletin 63, An Economic Study of the Use of Hocking Valley Coal with Underfeed Stoker Equipment by H. M. Faust. This bulletin covers a series of boiler tests made with coal from the Ohio No. 6 seam in the Hocking Valley District. Copies of the bulletin may be obtained by writing to the Engineering Experiment Station, The Ohio State University, Columbus, Ohio.

High-Pressure Steam and By-Product Power*

By DAVID MOFFAT MYERS
Consulting Engineer, New York

Mr. Myers, who has had a long and intimate identification with steam plant design, discusses the economics of high steam pressures especially as they apply to plants whose process steam requirements permit the generation of power as a by-product of steam production. Emphasis is placed on the importance of studying this possibility of effecting large economies at this particular time when reduction of overall manufacturing costs is a necessity in many lines of business. The author cites several cases which have come within his personal experience to show the extent of the savings possible. The accompanying charts and diagrams will be useful to engineers who wish to study this question with respect to their own plants.

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BUSINESS will gradually get back on its feet by process of modernizing its operations and eliminating needless waste and expense. That is the opinion of a certain important business man who is generally right.

In order to accomplish this result, the business man needs some information which he probably and naturally neither understands nor appreciates at the present time.

But, before indicating the trend of that special information, let me call attention to a fact which is generally overlooked, and one which has been emphasized by my friend, George Edwards.

A twenty-five per cent reduction in power and steam cost may easily mean a twenty-five per cent gain in the net profits of the business. Suppose, for example, the power cost is ten per cent of the manufacturing cost, and net profits are also ten per cent of the same item. Then if, by modernizing the steam and power services, their cost is cut one-quarter, there will be twenty-five per cent added to the net profits.

Many plants are showing a net profit of not only less than ten per cent but less than nothing. Consequently, such an improvement in power will often change the records from red ink to black.

If you go out and get $100,000 a year more sales for your product, which today is no simple matter, your net profit if any will be increased perhaps ten per cent or $10,000 a year. Whereas, if you make a power improvement of $100,000 a year, you have added ten times as much to net profits as the new business would have brought you.

One more fact before we talk about high pressures. While business has been going through its vicarious cycles of booms and slumps, the art of power engineering has been making steady and very important advances. The result is that any industrial management which has not for the past ten years subjected its steam and power costs to the study of specialists is missing one of the very few and very best opportunities for profits that exists today.

With modern engineering practice, these opportunities are many. But it is my object in this article to concentrate upon one of those pertaining to industry which derives from the recent developments in high pressure steam. These developments mark the greatest and most outstanding features of the last ten years of power plant progress.

They are the direct result of research and application in the central station industry in which a maximum of kilowatt hours per dollar is the chief object. High steam pressures have produced striking economies in the purely power field. But these economies are small compared to the savings which can often be produced in industrial plants by application of similar or even lower pressures.

While no one has attempted to specify at what point high pressure steam graduates from low pressure, we can at least say this. The high pressures of ten years ago are called low pressures today. And the upper limit of high pressure steam is approximately 3200 lb. per sq. in., the dew point at which on further pressure the steam condenses back to water. The installation of a 3200 lb. boiler on a Hamburg-American liner has recently been announced. This is interesting, particularly on account of the safety and reliability of high pressure steam as indicated by its adoption for marine propulsion.

* All rights reserved by the author.

Now we come to high pressure steam for industrial plants. Incidentally, plenty of such installations have been in successful operation for amply long periods to have eliminated all experimental features from present day new applications.

For many years exhaust steam from engines and turbines has been utilized for building heating and for low pressure steam processing, that is where the pressure and temperature requirements are low, ordinarily corresponding to from 1 to 15 pounds. It is well understood by plant owners that when all the exhaust is thus utilized, it replaces its equivalent of the expensive direct steam from the boilers. This equivalent is in the range of some 90 per cent. That is to say, the exhaust steam contains that proportion of the heat of the direct boiler steam. Hence, when so utilized, the steam used for power alone amounts to only ten per cent of the total. Thus the power generated from process or heating steam is virtually a by-product of that steam.

The new and important fact to be grasped by plant owners is that the same order of economy can now be secured when the steam pressures required by process are high. This means that whereas exhaust steam was formerly available at pressures of say one to thirty pounds, it is now possible and successfully applicable at virtually any pressures desired.

Thus, an industry generating steam at say 150 lb. for general process and manufacture can now secure from this steam a large quota of electrical energy at a very slight extra expense for fuel. Take for example a plant generating a minimum of 80,000 pounds of steam per hr. at a pressure of 145 lb. gage, and suppose this steam is used for process and general manufacturing purposes, including possibly building warming and miscellaneous steam using equipment, such as pumps, air compressors, small engines, etc. Suppose, further,

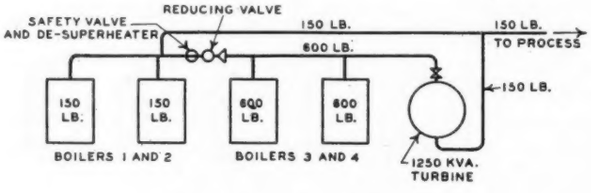

Fig. 1—Steam flow diagram.

that this plant buys electrical energy at a maximum demand of 2000 kw. Then, by raising the initial steam pressure to 595 lb. gage with 170 deg. superheat, and using a turbine-generator as a reducing valve between the boilers and the 145 pound process line, this plant can make all of its electrical energy with the same quantity of steam it is now generating.

This same quantity of steam costs a little more to generate, amounting in this case to 11.25 per cent, if the feedwater to the boilers is figured at 212 deg. fahr. The steam per kilowatt hour will be 40 lb., of which only 11.25 per cent is chargeable to power. This is the heat equivalent of 4.5 lb. of steam per kw-hr., whereas the average steam used per kw-hr. output in central station power plants is in the neighborhood of 16 lb. By the time the energy has reached the consumer's switchboard, the transmission and transformer losses will have increased this rate very considerably.

Consequently, our manufacturing plant cited above can make its own power for about one-quarter the amount of steam required by the central station.

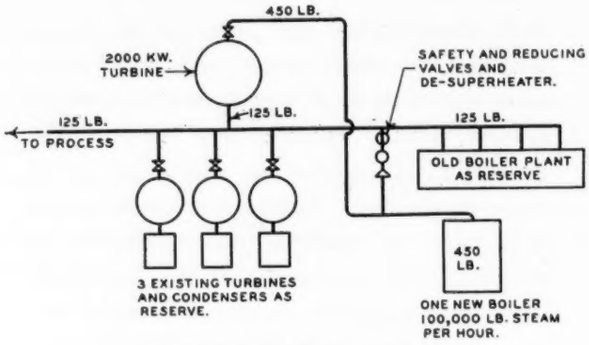

Fig. 2—Steam flow diagram.

This simple example typifies the opportunity for the economical application of high steam pressures to industrial plants.

There are three kinds of industrial situations in which by-product power can be made in this manner. (1) Where steam is needed for process or heating only. (2) Where steam is needed for power alone. (3) Where the requirement is a combination of these needs. With the same steam and power needs the economy will be the same in each situation.

An example of situation (1) is typified by the case of a rubber manufacturing plant buying all its power and generating all its steam at 150 lb. pressure for vulcanizing and general process work. Here in a certain actual case it was found possible to save a net $60,000 a year in reduced consumption of purchased current by investing $150,000.

Replacing two of the existing boilers with 600 lb. units and the proper degree of superheat and installing a 1250 kva. turbo-generator to receive this steam and exhaust into the old 150 lb. steam main were the principal changes involved. Fig. 1 illustrates the steam connections in simplified form.

Situation (2), where steam is used for power purposes only, may be exemplified by the case of a steel mill where power may be "skimmed" off the top of the present steam system. Practically all steam is used for power purposes, and in addition a very large sum is expended annually for the purchase of supplementary electric energy.

While process steam is not involved, the figures on this plant show that high-pressure, steam-driven turbine units, exhausting in turn into the present high pressure 150 lb. system, would eliminate an electric bill of $200,000 a year for a capital outlay of about $400,000. This is a good example of

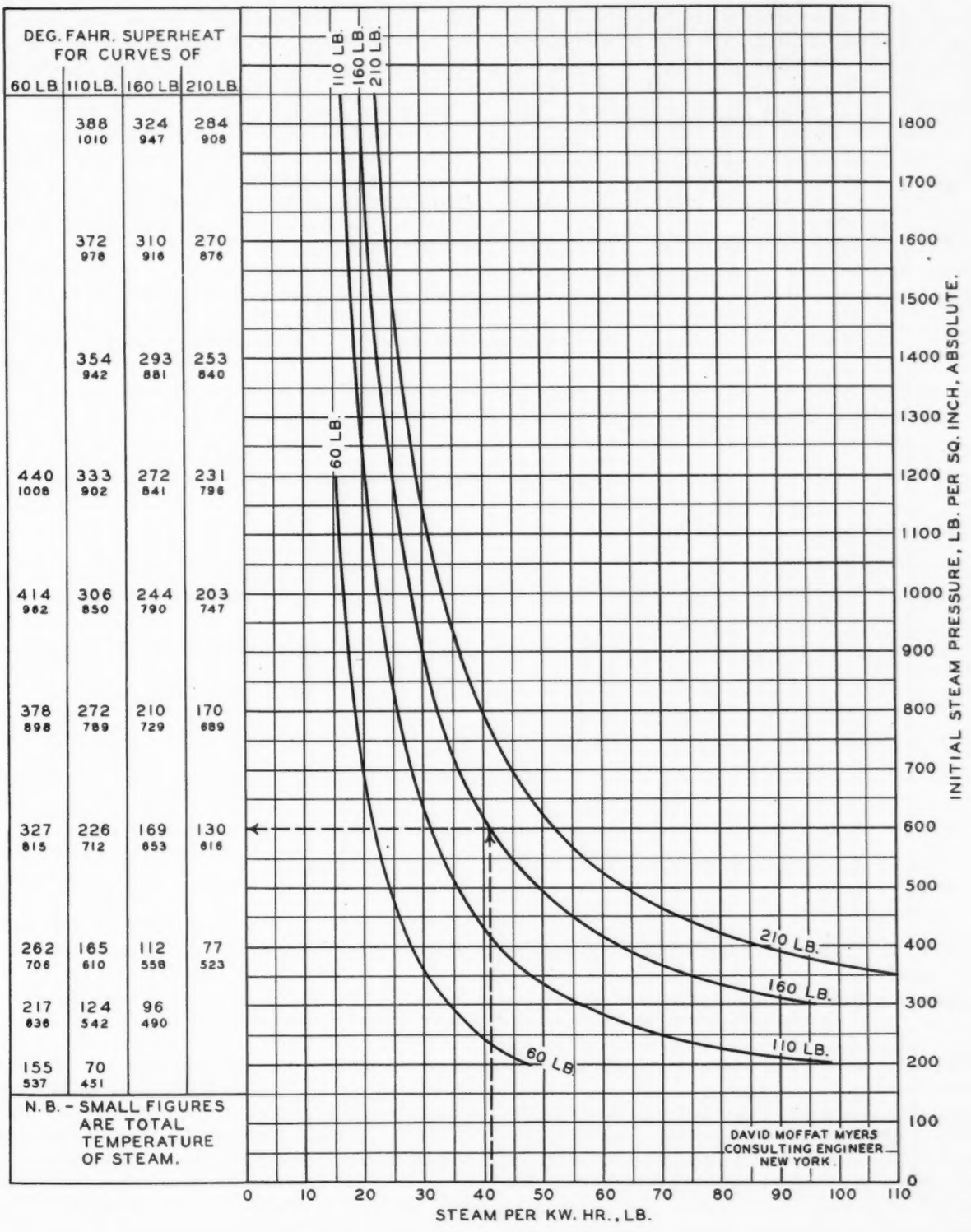

Fig. 3—Water Rate Chart—Initial steam pressures and superheat. Back pressures at zero superheat. Curves are lines of constant back pressure.

Example:—Required water rate 41 lb. at 160 lb. absolute with 0 deg. superheat in exhaust. The necessary initial steam pressure will be 600 lb. with 169 deg. superheat (see dotted line).

"compounding" an existing plant with high pressure steam which would permit skimming off the top of the same quantity of steam some 16,000,000 kw-hr. per year as by-product power.

Situation (3) represents a combination of processing and compounding. The case of a chemical manufacturing company furnishes a good example. As differing from the other two cases quoted, this plant makes all its own power. This is generated by several fairly efficient steam turbine units operated condensing with an initial pressure of 125 lb. A large quantity of steam at this pressure is also supplied from the boilers for chemical processing.

Under these conditions, as before, a high back-pressure turbine may be superimposed over the present turbines and would exhaust into their throttles and at the same time into the 125 lb. chemical processing main, as illustrated by the diagram

There are many plants which already have high enough boiler pressure to make use of the back-pressure turbine and its large economies. In one such plant, a steam pressure of 250 lb. was available. Power was purchased for as little as a cent per kilowatt hour. Yet it was possible to install a back-pressure turbine, exhausting at 110 lb. into the mill line, which resulted in generating energy at the rate of four mills, including all charges.

High steam pressure in industry often carries another advantage, for very frequently existing power or steam generating equipment can be retained for emergency or breakdown service. This eliminates the necessity of purchasing reserve units and thus cheapens the cost of the installation.

Then there are very attractive opportunities to make all or a part of the power as by-product, while depending upon purchased current in parallel for supplying the balance automatically and

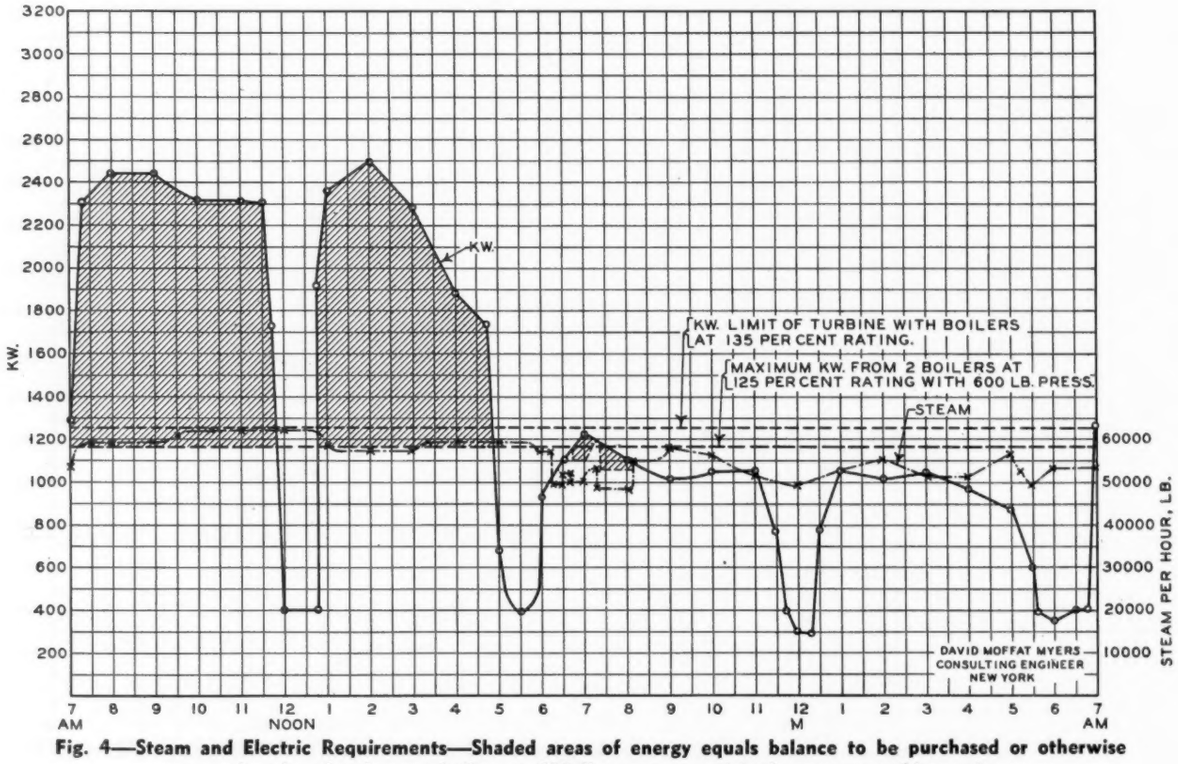
KW.
KW. LIMIT OF TURBINE WITH BOILERS AT 135 PER CENT RATING.
MAXIMUM KW. FROM 2 BOILERS AT 125 PER CENT RATING WITH 600 LB. PRESS. STEAM
DAVID MOFFAT MYERS CONSULTING ENGINEER NEW YORK
STEAM PER HOUR, LB.
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Fig. 4—Steam and Electric Requirements—Shaded areas of energy equals balance to be purchased or otherwise secured under plan for two boilers at 600 lb. pressure and back pressure turbine units.

in Fig. 2. However, one interesting difference in operation occurs.

Steam for process is drawn from between the high and low pressure turbines as automatically required, while the old low pressure power units become the low pressure expansion stages of the combined high and low pressure units. The consolidated arrangement, therefore, provides both the economy of compounding and that due to by-product power through the use of the exhaust from the high pressure power unit for process purposes; no direct steam being used for process.

The saving here will amount to $100,000 a year, chiefly in reduced fuel cost, with a capital outlay of about $260,000.

using the outside power connection as reserve or breakdown service. Such a scheme was the basis of the example of situation (1), illustrated in Fig. 1.

It is not always necessary to install very high steam pressure to secure the desired economy. The object is to obtain from the quantity of steam already being generated a quota of energy to replace purchased power requirements or to bring about maximum net savings by compounding existing power units.

It is useless waste of money to install a higher pressure than that which will produce these results. For a given exhaust or back-pressure, the available output of kilowatt hours increases as the initial pressure is raised. While for a given initial

pressure the possible kilowatt hours will decrease with an increase of back pressure.

The problem generally resolves itself into solving for initial pressure and superheat to give a predetermined water rate per kilowatt hour at a given back pressure and superheat.

The necessary water rate is the steam demand divided by the power demand.

$$W.R. = \frac{\text{steam in lb. per hour}}{\text{kw.}}$$

Having determined this figure, the water rate for a steam generator unit is:

$$W.R. = \frac{3415 \text{ B.t.u. per kw-hr.}}{\text{efficiency of unit} \times \text{adiabatic heat drop}}$$

By assuming an efficiency of 65 per cent, I have, by use of the Mollier Diagram, determined water rate for back pressures of 60, 110, 160 and 210 lb. absolute, with initial pressures up to 1800 lb. with the necessary degree of superheat to give saturated steam in the exhaust. These results are shown on a series of curves, chart, Fig. 3, from which the required initial pressure and superheat can be picked off readily.

It is to be noted, of course that the efficiency of a turbine unit will vary with the governing factors involved. It is affected by size of the unit, the load at which it operates, and the initial and back pressure steam conditions.

While the chart will give results close enough for a preliminary estimate, any given case must, of course, be individually computed, based on the guaranteed water rate or efficiency of the unit at various points of its capacity.

In order to secure the most economical results with high pressure steam in industry, it is essential that an intimate engineering study and cost analysis be made. Upon this basis only can adequate plans be developed. Chart, Fig. 4, is taken from one such study to illustrate something of the method of analysis.

The power was all purchased and the fluctuating steam requirements did not vary in parallel with power demands. This is characteristic of the majority of cases.

A 1250 kva. turbine unit was selected as giving the most return per dollar, taking all facts into consideration, including capacities of existing boilers with proper reserves.

The chart denotes the power and steam demand for the main portion of the week only, the remaining portions being studied with similar but separate charts not shown here.

By applying the guaranteed water rates of the turbine-unit at various capacities to the steam demand of each hour of the twenty-four, the kilowatts available for such period was determined and plotted. The difference between the total power curve and the by-product power curve, that is, the shaded areas, would still have to be supplied from another source.

A study of available purchased power schedules proved this source more economical under existing conditions than the installation of additional power apparatus to carry this load and to furnish breakdown service.

In fact it was determined that two-thirds of the total power load could be carried by the back pressure turbine and that the cost of buying the balance at moderate rates covered without additional expense the necessary breakdown service for the turbine.

Furthermore, by the steam connections indicated in Fig. 1, the 150-lb. boilers could serve as reserve for the steam supply which normally would be supplied by the two new 600-lb. boilers. Thus 100 per cent reserve was economically provided for both power and steam supply.

The means for these important provisions will, of course, vary with the conditions to be found and studied in each plant.

If a plant owner does not know whether his steam and power conditions would permit of such economies as are here outlined, steps should be taken immediately to determine what economies may be available.

The country is entering upon a new business era; one of prosperity. But, it will also be a period of such readjustment to new conditions and of increased competition that only those businesses which are thoroughly modernized in operation can hope for the full rewards of the impending future.

Higher steam pressures and cheap by-product power will constitute an important factor in the better things to come. Those who are prepared will reap the rewards with which fortune ever favors the foresighted.

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Dr. William D. Coolidge Wins 1932 Washington Award

At a notable meeting held on February 24 at the Hotel Sherman, Chicago, the Washington Award for 1932 was presented to Dr. William D. Coolidge, associate director of the research laboratory, General Electric Company. Among Dr. Coolidge's achievements is the development of the ductile metallic tungsten which is now used for practically all filaments of incandescent lamps, vacuum tubes and in many other applications.

The Washington Award is presented annually by a commission composed of representatives of the four national societies of civil, mining, electrical and mechanical engineers and the Western Society. Its presentation is made the occasion of a brilliant meeting of the members of the five societies participating. The Award was established in 1916 by John W. Alvord, past president of the W. S. E., who desired to provide some form of recognition by engineers of meritorious service to mankind. The first award was made in 1919, and the most outstanding engineer of that time, Herbert Hoover, was elected the first recipient.

Combination Burning of Blast Furnace Gas and Pulverized Fuel

By OTTO de LORENZI

Combustion Engineering Corporation
New York

The author presents test data on a steam generating unit fired by blast furnace gas and pulverized coal in combination. He points out that while it is difficult, in conducting such tests, to ascertain the correct percentage of the two fuels burned, the factors which determine this relationship are subject to accurate measurement. In order to reach dependable conclusions, it is essential that the samples of coal, gas and combustion products analyzed be truly representative. The author describes the calculations required to plot curves from which the coal-gas weight ratios may be determined, and outlines a method for procuring satisfactory samples . . . The latter part of the article is devoted to a description of a control system that has been successfully applied to such installations; the concluding paragraphs discuss recent developments in furnace design and methods of firing which are being applied with marked success in plants using coal and gas in combination.

THE primary fuel in many recent steam generating units, installed in steel mills, is blast furnace gas. Because of load conditions or blast furnace operation, the available quantity of this fuel is not always sufficient to meet the steam demands. It becomes necessary therefore to make provision for burning a supplementary fuel. In a number of instances this fuel is pulverized coal.

In the burning of blast furnace gas, experience has taught that liberal furnace volumes must be provided if reasonably satisfactory results are to be obtained. With the conventional type of horizontal burner, the liberation rates should not exceed 12,000 B.t.u. per cu. ft. per hr. in an all-refractory furnace. The addition of water cooling makes it possible to operate at rates of from 18,000 to 20,000 B.t.u. per cu. ft. Because of these limitations, the furnaces are of generous proportions and well adapted for pulverized fuel firing.

Blast furnace gas is a lean fuel and contains a high percentage of inerts. Because of this fact the weight of the products of combustion per 1000 B.t.u. is high. This then results in a large percentage of heat being carried away in the stack gases. The obtainable efficiency is therefore lower than where a fuel having a more favorable gas weight to B.t.u. ratio is utilized. Coal, on the other hand, has approximately 50 per cent less weight of products of combustion per 1000 B.t.u. Consequently the stack gas loss is lower and the resulting efficiency higher. Therefore when these two fuels are burned simultaneously in a furnace the resulting efficiency will be higher than when gas alone is burned, but lower than when coal alone is burned.

Recently a series of tests were conducted on a boiler equipped to burn blast furnace gas and coal, separately or simultaneously as required. This particular installation is illustrated in Fig. 1. The boiler is of the four drum, bent tube type and contains 20,000 sq. ft. of heating surface and is designed for a pressure of 425 lb. per sq. in. The superheater, located behind the first baffle and in front of the second boiler bank, is designed to give a total steam temperature of 650 deg. fahr., when burning blast furnace gas. The air preheater, which is of the plate type, contains 18,060 sq. ft. of heating surface. The furnace is of the air-cooled refractory construction and its volume is 16,700 cu. ft. The lanes, in the air cooled wall, are connected to the suction inlet of the forced draft fan. The temperature of the air, in passing through the walls, is increased approximately 100 deg. fahr. and thus enters the preheater at about 170 deg. fahr. The cooling of the walls, in this manner, serves to reduce furnace leakage and minimize radiation losses. The pulverized coal is supplied by four, horizontal turbulent type burners through the lower part of the front wall of the furnace. The blast furnace gas enters the furnace through three, horizontal, mixing-type burners located under and slightly to the rear of the mud drum. All of the burners are of the forced draft type and are supplied with highly preheated air. A refractory-lined hopper bottom is provided to receive the coal ash

and the dust carried into the furnace by the gas.

This unit has been successfully operated on pulverized coal, blast furnace gas and a combination of these two fuels in varying percentages of each. When burning blast furnace gas, a maximum output of 128,500 lb. per hr. has been obtained at an efficiency of 72.4 per cent. The liberation per cu. ft. of furnace volume was 10,800 B.t.u. and the corresponding CO_2 at the air heater outlet was 21.4 per cent. When operating on a mixture of pulverized coal and gas, this same unit developed an output of 161,000 lb. per hour. The CO_2 at the air heater outlet was 17.9 per cent and the proportion of coal weight to gas weight was 16 to 84. Other tests were conducted at different outputs and various ratios of coal to gas. Because of the variation in the proportions of the two fuels, it is impossible to portray graphically the results as the points have a relatively wide dispersion, making it impossible to construct a performance curve which has any meaning. Table I gives the results of these tests.

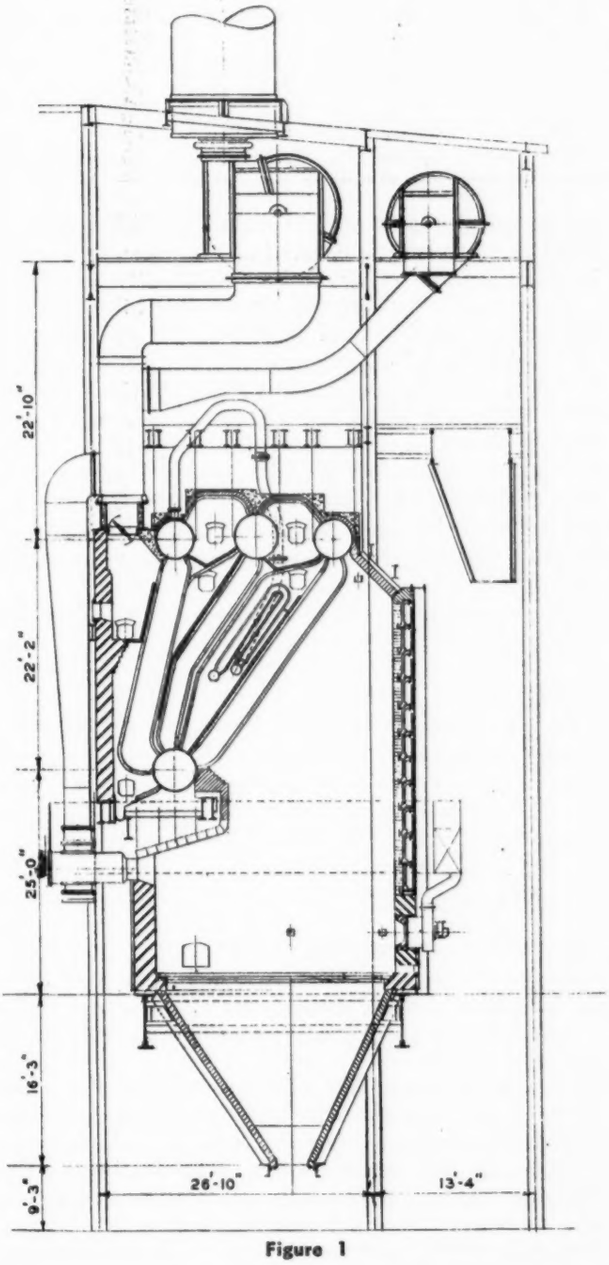


Figure 1

During all of these tests the boiler was operated under hand control. The ratings were maintained as near constant as possible. The coal feeders were run at a constant speed and the quantity of gas fired was kept as constant as possible. Variations in pressure of the gas supply, however, at times, slightly changed the proportion of the two fuels. As it was not possible to weigh or measure the quantities of fuel burned, the efficiency was determined by measuring the losses and obtaining the heat absorbed by difference. The results may be considered accurate to within plus or minus 1½ per cent.

The item of particular interest, in the tabulation, is the ratio of the coal to gas weight. The percentage of coal, in the mixed fuel, ranges from zero per cent to twenty per cent, by weight. The various tests were conducted at different steaming rates on the unit and therefore the efficiencies are not on a common basis. To make the results comparative, the exit gas temperature, at the air heater outlet, is assumed to be 500 deg. fahr. Efficiencies corresponding to temperatures higher than this are increased at the rate of 3 per cent per 100 deg. fahr. difference. We now have a new set of efficiency figures, all based on 500 deg. fahr. exit gas temperature, and all representing operation at approximately 12,000 B.t.u. per cu. ft. per hr. furnace liberation. With these data the curve, Fig. 2, has been constructed and, while there is still considerable dispersion of the points, the trend is definite. The conclusions drawn from this curve are that as the percentage of coal, in the mixed fuel is increased, the efficiency approaches that of all-coal firing, at the same rate of heat liberation. Had all of these tests been held within narrow limits, as to furnace liberation, and a wider range of fuel mixture utilized, these data would be far more valuable and conclusive. Nevertheless the factors presented are of considerable interest and certainly indicate the trend of efficiencies with combination firing. Furthermore the indications are that the ratio of the two fuels has been quite accurately established in all of the tests.

The principal difficulty in conducting tests as described above is to arrive at the correct percentage of the two fuels burned. However, the following outline will serve to indicate the method used.

The factors which enter into these calculations are subject to accurate measurement. The method is therefore a reliable one and the results are a true measure of the ratio of the two fuels burned. The first requirement is to secure a true composite sample of the products of combustion as they leave the unit. The sample should be continuously withdrawn and the rate should be proportional to the output of the unit. In this manner we are able to obtain samples, at various loads, which represent a definite proportion of the total products of combustion, passing through the unit. To obtain these samples, three or more pipes should be placed in

the gas stream, at the outlet of the unit. A gas traverse is then made to determine exactly where these tubes should be located, so that the samples withdrawn are a true composite representation of the products of combustion, leaving the unit. One of the sampling pipes is used for taking grab samples, at short intervals, throughout the test. To the other tubes large bottles are connected for withdrawing a continuous sample, over the period of the test, by water displacement. The average analysis of the grab samples and the continuous samples is a real measure of the composition of the gas stream leaving the unit. It is also necessary to obtain a continuous sample, over the period of the test, of the blast furnace gas being burned. A representative sample of the pulverized coal is also taken, so that a suitable analysis may be made. With these data it is now possible to proceed with the necessary calculations to establish the ratio of the two fuels burned simultaneously in the furnace. The first step is to compute, from the fuel gas analysis, the theoretical percentage of CO_2, resulting from complete combustion with zero per cent excess air. The same computations are made for the complete combustion of the pulverized coal with zero per cent excess air. The values just computed give us the two extreme points on our curve. From these results it will be seen that when burning all gas and no coal the resulting CO_2 is high. When burning all coal and no gas the resulting CO_2 is relatively low. Intermediate points for this curve may be computed by mixing the gas and coal in definite ratios of weight and then making the necessary calculations for CO_2 with zero excess air. The resulting curve will be similar to the one shown in Fig. 3. A variation in fuel analyses will change the points on the curve and it is necessary, therefore, to construct one for each set of local conditions or for major variations in fuel analyses.

After having established the foregoing curve, from the fuel analysis, we are in a position to determine the ratios of the two fuels burned in the furnace. The average analysis of the actual flue gas, taken during the test, are, by calculation, reduced to zero per cent excess air. This step then gives us the theoretical CO_2 of a fuel whose composition corresponds to the mixture of pulverized coal and blast furnace gas burned. By referring to the curve in Fig. 3, we are now able to determine the percentage weight of these two fuels entering the furnace, by reading the ratio corresponding to the intersection of the calculated CO_2 value with the curve. It is immediately recognized that the accuracy of the method outlined above depends upon obtaining a true average sample of the fuels as well as the products of combustion. If indifferent or careless sampling is carried out the results may be in considerable error and consequently valueless.

TABLE I

Test number	1	2	3	4	5	6	7
Evap. lb. per hr., actual	128,500	156,000	153,000	161,000	157,000	147,000	153,000
Temp. flue gas at boiler outlet	815	850	786	790	773	777	808
Temp. flue gas at air heater outlet	643	650	610	583	576	690	625
Temp. air to preheater	174	167	170	172	165	182	176
Temp. air from preheater	588	642	605	578	564	594	601
Approx. proportion coal to gas	0–100	11–89	9–91	16–84	20–80	8–92	4–96
CO_2 air heater outlet	21.4	19.0	18.8	17.9	15.2	17.7	18.4
O_2 air heater outlet	3.4	2.5	2.8	3.1	5.7	4.8	4.8
CO air heater outlet	0	.3	0	.5	.1	0	0
Efficiency—per cent	72.4	75.6	78.2	78.1	76.4	77.2	75.4
B.t.u. per cu. ft. furnace vol.	10,800	12,400	11,900	12,400	12,300	11,400	12,200

In an earlier paragraph it was stated that, during the tests cited, the coal feed and gas supply were maintained relatively constant, by manual control. Under actual daily operation the conditions are entirely different. The gas supply is generally of a widely fluctuating nature, the governing factor being the demands of the blast furnace and not the requirements of the steam plant. Actual steam demands may increase with decreasing gas supply or they may decrease with increasing gas supply.

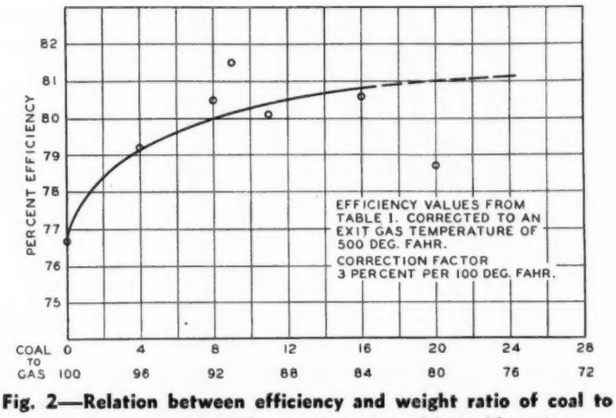


Fig. 2—Relation between efficiency and weight ratio of coal to gas at an approximately constant rate of heat liberation.

Under these conditions there is generally a considerable amount of adjustment required to maintain the steam pressure. Pulverized coal, the supplementary fuel, must be fed in increasing or decreasing amount depending on the gas supply, as well as on the steam demands. Because the variations are sudden and frequent, it is hardly possible for an operator to make the necessary adjustments quickly enough to maintain steam pressure. Therefore, to be able to make fullest use of the combination fired unit, with its extreme flexibility, it is necessary to provide suitable automatic or semi-automatic regulation. While a system of this type may appear, from a description of its functioning, to be relatively complicated, a study of its operation will indicate its real simplicity.

A system designed to meet the requirements of a combination fired unit has been in operation for several years. The functioning of this particular installation, which is of Hagan manufacture, may be described in the following manner:

1. A master controller regulates the supply of blast furnace gas according to the steam demand. Provision is made, under conditions of low steam demand, to vent the excess gas to the atmosphere.

2. A forced draft type of gas burner, having equal gas and air outlet areas is provided. With a

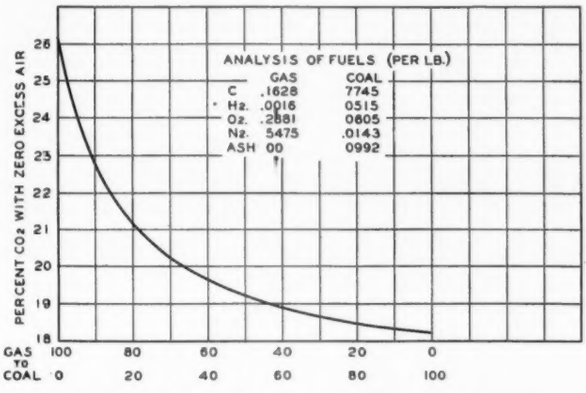


Fig. 3—Relation of theoretical CO_2 to weight ratio of coal and gas.

design of this type it is possible to provide a regulator which will maintain the air pressure equal to that of the gas. In this manner, uniform mixing and proportioning of the air and gas supply are maintained under all conditions.

3. A suitable control is provided to prevent the boiler plant from robbing the remainder of the mill of its gas supply. This particular control is usually designed to function when the gas pressure, in the mains, drops below a predetermined minimum.

4. The pulverized coal burners are automatically cut in when there is insufficient gas to meet the steam demands. The amount of air supplied to the burners is governed by the rate of coal feed.

5. Changes in furnace draft serve to operate the boiler damper, as well as the induced draft fan. Intermediate openings of the damper, between a predetermined minimum and maximum, take care of minor variations in draft. Exceeding the maximum or minimum limits of opening will either increase or decrease the induced draft fan speed.

6. To prevent the overfeeding of fuel to the furnace, because of sudden increase in gas supply, an interlock, between the pulverizer coal feeder and induced draft fan, is provided. When this condition occurs the induced draft fan is immediately brought up to full speed. The interlock then functions to change the pulverized coal supply control from functioning on steam demand to functioning on furnace draft. Under these conditions the furnace will operate on the full quantity of gas plus the amount of coal which can be burned without developing a positive pressure in the furnace.

7. Should the induced draft fans fail to function, the fuel supply is automatically cut off. On restarting these fans, as a safety measure, they must be manually cut in.

8. It is possible to switch controls to permit manual operation. When operating manually only the furnace draft control and the interlock between induced draft fan and pulverized coal feeder will function, to prevent overloading the furnace.

With a control system as described, it is possible to meet the conditions existing in a steel mill boiler room. The average monthly efficiency will be considerably higher than if manual control is used. The main reasons for this difference are:

(a) The fuel supply is always correctly proportioned to the steam demand.

(b) Sensitive regulators are able to instantly adjust for minor changes in conditions.

(c) The full available flexibility in the unit is made use of.

Where there are a number of units in the boiler house, it is possible, sometimes, to carry out the regulation in a somewhat different manner. The available gas supply may be burned in say two of the units without relation to the steam demand on the plant. The variations in output due to demand, as well as fluctuation in gas supply, are met by regulating the coal pulverizing and burning equipment, on one or more of the remaining units. The control system, under this scheme of operation, becomes quite simple. A regulator changes the rate of milling and delivery of the pulverized coal to the burners, with the change in steam flow. The burner dampers are regulated to maintain the correct proportion of secondary air, to the coal being burned. The induced draft fan or boiler dampers are operated by a furnace draft regulator to maintain the necessary furnace suction. One of the main disadvantages of this system of operation is that the gas-fired units are not always operated to full capacity and it becomes necessary therefore to carry more boilers on the line to meet the steam demand. In order to reduce capital expenditure, it will immediately be realized, when designing a new plant, that it is necessary to keep the installed capacity to a minimum. The minimum and maximum load requirements, as well as the load factor and duration of peak, will determine the most economical number and size of units to install. In addition to the actual requirements, sufficient spare capacity must be provided to assure continuity of operation. By designing the units so that two or three fuels may be burned, separately or in combination, the installed rated horsepower may be kept to a minimum.

The installation shown in Fig. 1 is one in which the pulverized coal is supplied to the furnace by feeders from overhead bunkers. Several recent installations have been made using the so-called unit system. In Fig. 4 is shown a large steam generator installed in the Monessen, Pennsylvania, plant of the Pittsburgh Steel Company. This unit is equipped with the control system just described. The boiler is of the Ladd three drum, bent tube type containing 14,250 sq. ft. of heating surface. The furnaces are of the hollow air cooled wall type having an

effective volume of 10,000 cu. ft. The air, for combustion, in passing through the lanes in the furnace walls, is heated to approximately 140 deg. fahr. A part of this preheated air is used for drying the coal as it is being milled.

The burners, for both blast furnace gas and coal, are located in the front wall of the furnace. The Steinbart burners, for the gas, are provided with the conventional refractory "dog house." Directly above them are the two horizontal, turbulent forced draft type, pulverized coal burners. Each one of these burners is served by a Raymond four roll mill, operated on the unit mill system. Variable speed motors are provided on both the mill and the exhauster. This particular type of mill is well adapted to unit firing as a uniform fineness of coal is produced over a wide range of output. Another advantage is that failure of coal supply to the mills does not mean instant loss of ignition. The usual type of unit mill carries no reserve supply of coal in the mill housing. The roller mill does carry such a reserve supply and is able to operate from three to five minutes before ignition is lost. This time interval is usually more than sufficient to span the average interruption in coal supply.

The test data presented show, with simultaneous firing of blast furnace gas and pulverized coal, that efficiency is a function of the ratio of the weights of the two fuels in the burning mixture. The calculation method described presents a relatively simple way of determining the weight ratio from readily obtainable analyses. The illustrations, Figs. 1 and 4, show two recently installed and successfully operating units. The main differences in the two units are the location of the gas and coal burner. In Fig. 1 the gas burners are located under the mud drum and opposite the coal burners. This means that when operating on one fuel, the burners for the other are so located as to be subjected to direct impingement of flame and unless a certain amount of air is allowed to flow through them, their life will be relatively short. The gas burners, in this instance, are in such a position that, because the blast furnace gas is slow to ignite, a considerable quantity of unburned fuel will find its way into the first boiler bank. This fuel will then fail to ignite and so there is a definite efficiency loss, and ratings will be reached with extreme difficulty. When gas and coal are fired simultaneously turbulence is set up where the two opposing flames meet in the furnace. Local high temperatures result, and, if the gas carries any appreciable amount of dust, sintering will occur. Slag deposits and birdnesting in boiler tubes will be a direct result.

The installation shown in Fig. 4 has the advantage of providing maximum travel of both the gas and coal streams. As these streams travel in the same general direction, little or no turbulence is set up and there are no local high temperature zones in the furnace. Slagging and birdnesting troubles are minimized. Since all burners are located in the same wall, there is no danger of flame impingement and their life is materially lengthened.

The remarks, in the preceding paragraphs concerning turbulence in the furnace and local high temperature zones, should not be misunderstood. In furnaces of the particular types illustrated, these are things to be avoided. Where adequate provisions are made to take care of the resulting condition, it is desirable to secure the maximum amount of obtainable turbulence in the furnace. It is because of this turbulence that it is possible to operate at rates of high heat liberation in all water cooled furnaces. Units designed on the principle of corner firing, to obtain maximum turbulence in the furnace, have successfully operated on varying mixtures of pulverized coal and blast furnace gas. The heat liberation, in the furnaces of these units, has been maintained well above 30,000 B.t.u. per

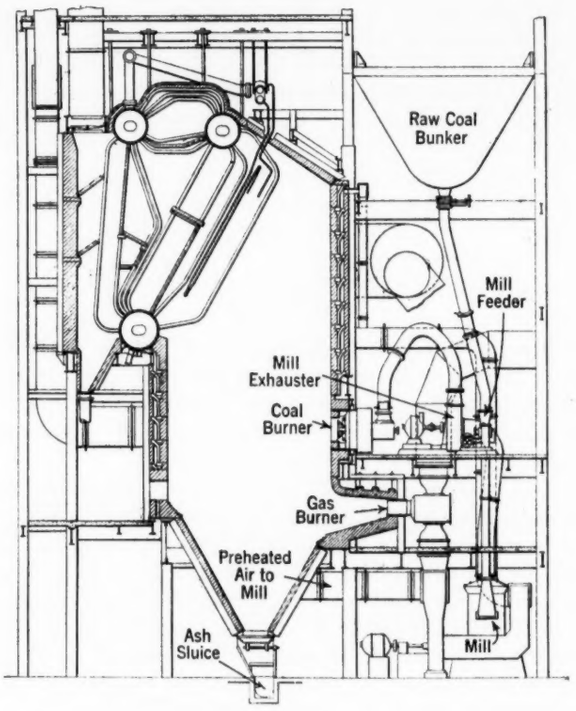
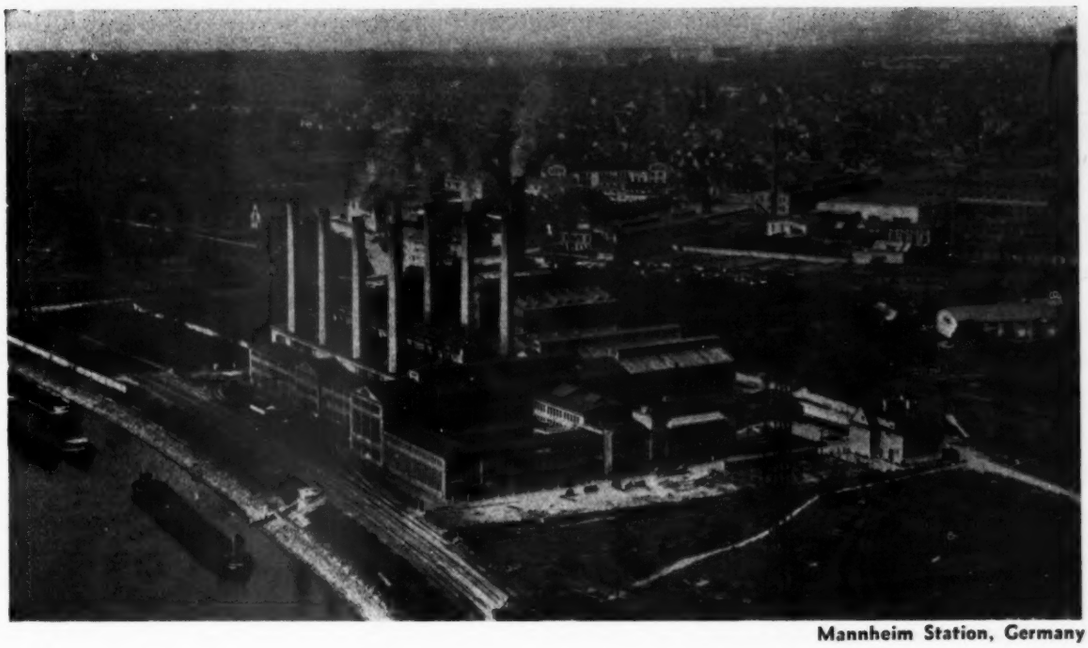


Figure 4

cu. ft. for long periods. Their availability has been considerably higher than the standard conventional type of unit, operated at much lower rates of heat liberation. This then serves to indicate that design will determine the extent to which turbulence is allowable in the furnace.

The ultimate success, of a unit employing combination firing of blast furnace gas and pulverized coal will depend on furnace design, burner type, and burner location. Automatic or semi-automatic regulators will be of valuable assistance in meeting the steam demands and in maintaining a correct balance between the two fuels. The calculation method previously outlined will be of material assistance in checking the performance of the unit from time to time. Full furnace water cooling and corner firing must be given serious consideration because of the compactness of design made possible by high liberation rates.



Mannheim Station, Germany

High Pressure Operation at Mannheim

By DAVID BROWNLIE, LONDON

Mr. Brownlie briefly describes the high-pressure boiler and turbine installation at the Mannheim Station, Germany and tells of some of the operating difficulties experienced. These difficulties appear to be due to causes not inherent in high-pressure but which are more apt to manifest themselves under the conditions of high-pressure operation.

IT is well known that when super-pressures of say 1000-1800 lb. per sq. in. were first used in power stations a few years ago all kinds of serious troubles were expected. However, extensive practical experience in the United States has shown these fears were groundless, and all the more or less minor difficulties experienced with super-pressure boiler plants have been due to one cause or another, feedwater for example, which would have given rise to the same problems if medium pressures such as 400-750 lb. per sq. in. had been adopted. Some famous man once remarked in his old age that his life had been full of troubles, most of which never happened, and super-pressure steam practice also seems to be a good example of the fact that anticipation is usually much worse than realization.

Opposition to new ideas invariably characterizes the normal course of evolution and the present case is no exception to this rule. Since the earliest days of steam utilization, the idea of high pressures has been strenuously opposed. It may be remembered that about 130 years ago James Watt, one of the greatest engineers of all time, prophesied all kinds of terrible disasters if more than 6 lb. steam pressure was used, and generally speaking the most authoritative engineering literature of the past century is full of warnings against the use of high steam pressure.

In this connection it will be interesting to give the experience of one of the best-known power stations in Europe, that is, Mannheim in Germany, of the Grosskraftwerk Mannheim A.G. The author wishes to express his appreciation to the Director of this plant, Dr. F. Marguerre, a well-known steam and power expert, for much of the information given in this article, and also for the photographs and illustrations reproduced.

The latest extensions at Mannheim, carried out in 1928, include the installation of two Hanomag boilers and also one Humbolt boiler, each of 154,-280 lb. evaporation per hour, operating at 1485 lb. per sq. in. pressure and 860 deg. fahr. superheated steam temperature, driving two Brown-Boveri back-pressure turbines, one of 7000 kw. and the other of 4800 kw.. exhausting at 308 lb. per sq. in.

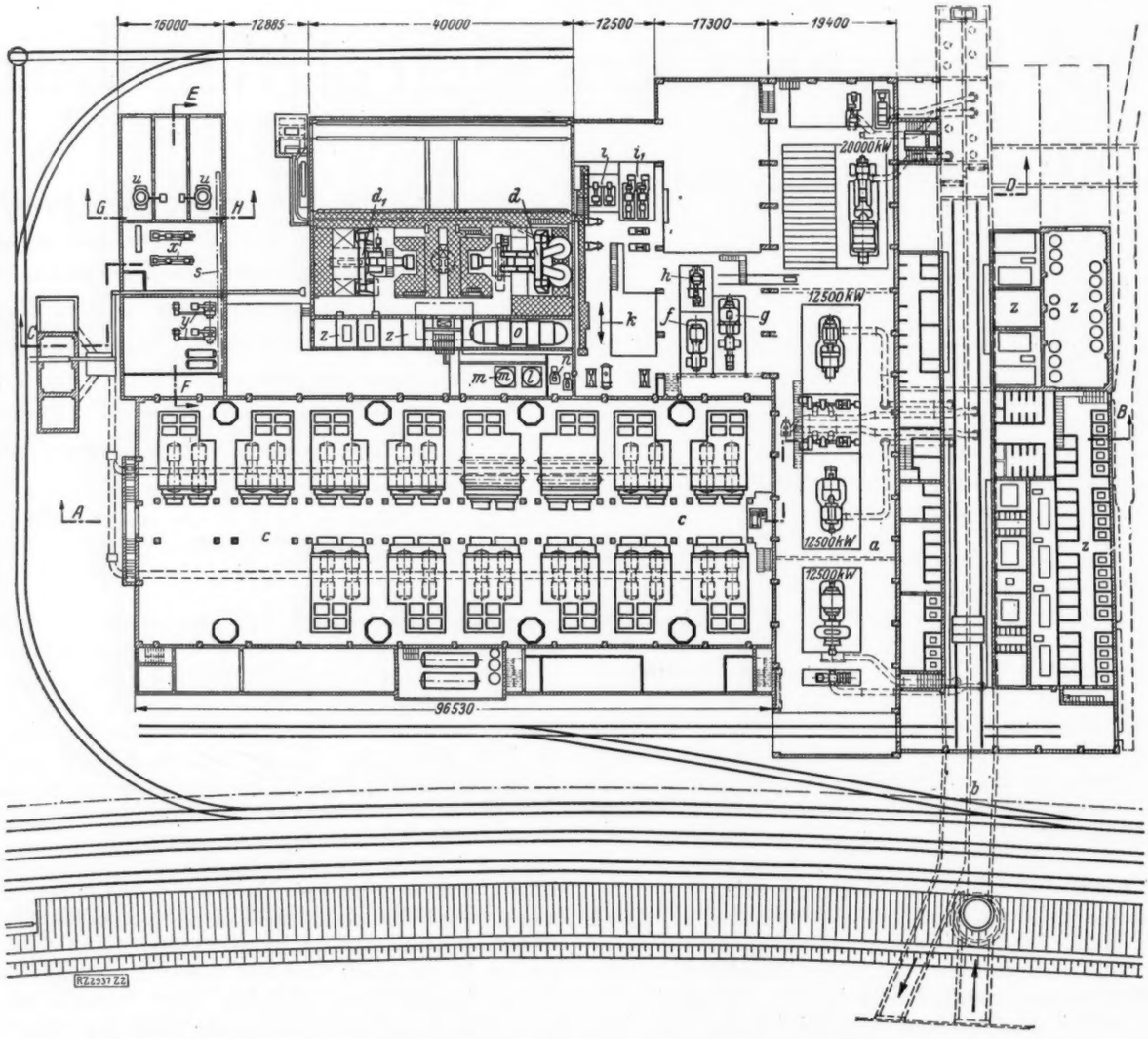
pressure to the medium pressure steam mains of the already existing station.

The net result of the operation of this super-pressure plant at Mannheim, as given in a detailed and highly interesting paper by Dr. Marguerre at a meeting this year of the Vereinigung der Gross-kesselbesitzer (Association of Large Boiler Owners), is that the performance has proved to be quite satisfactory and that the problems that have had to be solved bear little relation to the pressure used, being chiefly concerned with corrosion of the boiler tubes which has more or less equally affected both the super-pressure and the medium pressure boilers, although for some unexplained reason originating in the new plant. This, naturally, for a long time led everyone to conclude the cause of the trouble was the pressure, which was afterwards proved conclusively not to be the case.

Before 1928, the plant at Mannheim had 14 water-tube boilers, each of 6458.4 sq. ft. heating surface, operating at 279 lb. per sq. in. pressure and 662 deg. fahr. superheated steam temperature, and three Brown-Boveri turbo-generator sets of fairly modern design, each of 12,500 kw. capacity, together with one Brown-Boveri 20,000 kw. turbo-generator.

When the time came for the extensions, it was decided to instal super-pressure boilers with back-pressure turbines exhausting to the existing mains at about 279 lb. pressure, so as to increase considerably the overall thermal efficiency of the station, while at the same time retaining in use the whole of the existing medium pressure plant. Some considerable risk, however, was taken because at that time 1485 lb. per sq. in. pressure was the highest that had ever been used in Europe; but Dr. Marguerre and his associates decided this was the best policy, in preference to using say 800-1200 lb. pressure. One of the factors favoring this decision was that, in the event of entirely new designs of super-pressure generator coming into use, such as the "Benson" and "Loeffler" with about 1500 lb. pressure as the standard, there would still only be two steam pressures operating in the station.

Another factor was the space limitation at Mannheim, which rendered it imperative to use the highest steam pressure possible, and it was for this reason also that the highly interesting method is



Plan view of the Mannheim station. D_1 and d high pressure boilers, f and g high pressure turbines.

being used of re-heating the back pressure steam from the super-pressure turbines by means of heat interchange with the super-pressure live steam instead of the usual arrangement of re-heaters operated by combustion gases from the boilers.

The new Hanomag and Humbolt super-pressure boilers are of the twin-drum, vertical-tube type, very similar in design to the medium pressure 279 lb. units, the heating surface of the two Hanomag boilers being 8988 sq. ft. each and that of the Humbolt boiler, 7707 sq. ft.; the corresponding figures for the superheaters are 4876 sq. ft. and 7534 sq. ft. Air heaters are installed which raise the temperature of the air delivered to the combustion chambers to 482-662 deg. fahr. Feedwater is delivered to the boilers at about 518 deg. fahr. The rate of evaporation obtained is 20.4 lb. per sq. ft. of heating surface per hour.

The boilers are fired with pulverized fuel, the system being of the bin-and-feeder type. Steam-heated rotary cylindrical dryers are used. One of the reasons for this is that the coal generally contains more than 10 per cent moisture, and in 1928, when the equipment was ordered, the present high efficiency had not been attained with pre-drying of the coal direct in the pulverizer by means of hot combustion gases or air. The decision to use pulverized coal was largely influenced by general design considerations and operating conditions. The design of the super-pressure boilers means a very small water content, while there are considerable fluctuations in the demand for power at Mannheim because the station is interconnected with hydro-electric power plants. Hence it was decided that pulverized coal equipment was much preferable to mechanical stoking, because of its greater flexibility permitting shutting down and starting up again in a comparatively few minutes.

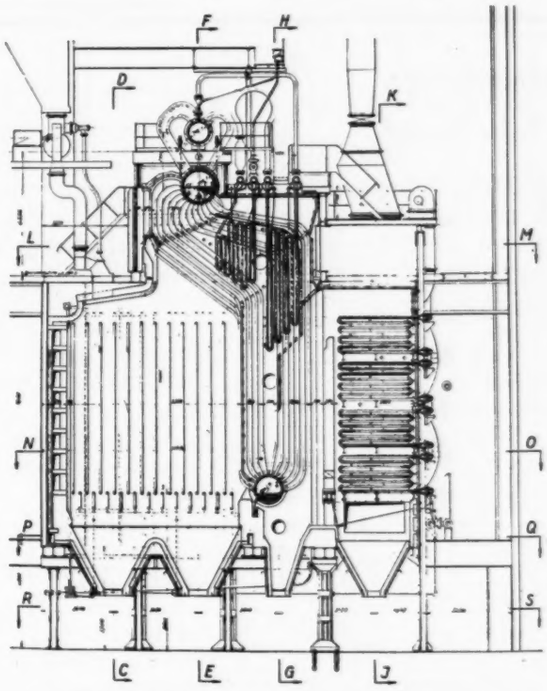
Also because of these general conditions a constant pressure steam accumulator is installed, with a capacity sufficient to provide 5000 kw-hr. This equipment is said to be giving very good results; for example, it allows the load to be varied very rapidly within a range equivalent to 60-100 per cent of the total evaporation in the boilers without altering the rate of firing.

The two Brown-Boveri super-pressure turbines of 4800 kw. and 7000 kw. operate normally at a minimum pressure of 1411 lb. per sq. in. at the stop valve, and a minimum steam temperature of 797 deg. fahr. while the maximum steam temperature may be 842 deg. fahr. The actual exhaust pressure is 294 lb. per sq. in. at a temperature of 480 deg. fahr.

The 7000 kw. turbine is of the twin-cylinder type, and the steam used to heat the feedwater is taken from this unit. Both turbines operate at 3000 r.p.m. The casings are of heavy cast steel and the blades of chrome nickel. The drums are built up in sections fitted on the shafts by steel rings.

With regard to the super-pressure steam piping between the boilers and the turbines, this consists of steel tubes with an internal diameter respectively of 4.9 in. and 6.8 in., the thickness being 0.55 in. and 0.66 in. The flanges are screwed on and welded to the pipes. The packing between the flanges is a special composition of soft iron, nickel, and Monel metal.

The feedwater arrangements are of a somewhat complicated character, involving 2-stage heating



Sectional elevation of Hanomag high pressure unit.

from the super-pressure turbines at 152 lb. per sq. in. and 81 lb. per sq. in., while there is also a certain amount of very hot condensed water available from the reheater equipment. Because of this the boiler feed pumps have to handle water at 392 deg. fahr. under average pressure conditions of 308 lb. per sq. in. Four centrifugal pumps are installed, each with a maximum duty of 200,000 lb. per hr., two being by Klein, Schanzlin and Becker, each driven by an Escher-Wyss steam turbine, and two by Gebrüder Sulzer, each driven by a Brown-Boveri electric motor. The drives for all four pumps are of the variable speed type operating on the Scherbius automatic control principle.

The pumps are of the single-flow type, with bodies either of cast steel or of forged steel rings held together by heavy bolts, and having either Monel metal or nickel-bronze impellers. The results generally are stated to be very satisfactory except that the cost of maintenance is high because of the severe erosive tendencies of water under conditions of nearly 400 deg. fahr.

Included in the feedwater layout is a storage tank with a complete equipment of automatic valves, the hot water entering at the top from the feedwater heaters. Since at low load more water flows through the feed heaters than is required for the boilers, this arrangement builds up a big reserve for the peak demands.

(Continued on page 48)

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Refractories

By F. H. Norton

HERE is a book which is a concise, comprehensive treatise on refractories used in the construction of all types of furnaces, embodying the history, the mining and preparation, fabricating, testing and specific uses of the refractories in general use.

It deals mainly with the fundamental processes involved in the manufacture and use of refractories, and descriptions of the manufacturing processes have been confined to American practice. The reason for this, the author states in his preface, is to keep the book within reasonable size.

The book contains a considerable amount of new material and one of its outstanding features is the inclusion of much first-hand data which the author obtained from manufacturers of refractories.

This book should prove of unusual value to the student, the user and tester of refractory materials as well as to those having to do with the operation of glass, chemical, power or metallurgical plants.

It is exceptionally well illustrated with photographs, tables and curves and numerous photomicrographs.

Size overall, 6 x 9 inches and contains 594 pages and 376 illustrations. Price $6.00.

American Gas Practice. Volume 1–Production of Manufactured Gas

By Jerome J. Morgan

IN this second edition of his book, the author has changed the name from "Manufactured Gas" to "American Gas Practice" this change in name being rather with a view to the contents of a future second volume than any influence it may have on the contents of the first volume, although a thorough revision has been made of the contents and the book has been built in more convenient form. The author seems to have been very successful in the attempt to give a complete picture of American Gas Practice. While the book is labeled a "textbook" and would be suitable for use in the class room, it is of great value as a reference book for chemical engineers who are interested in solid fuel processing. In fact the elementary textbook nature is of value to those who have not kept in constant touch with the latest practice. Mr. Morgan has had the assistance and advice of a distinguished group of engineers in the preparation of the book. It is strongly recommended as a reference volume on the subject. The volume contains 969 pages. Size 6 x 9 inches. Price $8.00.

Proceedings of Third International Conference on Bituminous Coal

THE Proceedings of the Third International Conference on Bituminous Coal which was held under the auspices of the Carnegie Institute of Technology, covering all papers and discussions delivered at the four-day meetings, are now available. Contributions of scientists from Belgium, France, Germany, Holland, Italy, Japan, Roumania, Spain, Sweden, and the U.S.S.R. have been translated into English. Illustrations and graphs are incorporated in the books. Of the 98 papers included in the proceedings, 39 were contributed by Americans, 22 by British scientists, 20 by German fuel technologists and seven by French. Among the subjects treated in the two volumes are,—Economics of the bituminous Fuel Industry; Competition between Fuels; Low Temperature Carbonization; High Temperature Carbonization; Coal Carbonization Problems; Gasification; By-Products; Hydrogenation and Liquefaction; Railway Fuel; Steamship Fuel; Domestic Utilization of Coal; Power Plant Fuel; Pulverized Fuel; Smoke and Dust Abatement; Preparation; Coal Cleaning; Origin and Classification; Stream Purification. These books are regarded as standard reference works on fuel technology. Two volumes approximately 800 pages each, size 6 x 9, full cloth. Price per set of two volumes, $15.00.

Symposium On Welding

THE eleven papers presented in a Symposium on Welding held at the second Regional Meeting of the American Society for Testing Materials, Pittsburgh, on March, 1931, are now available in book form. In addition to the papers presented, the discussions on processes, materials, applications, inspection and testing are also included. The book covers newer processes for steel and alloys by gas and electric arc, types of joints, fusion welding and specifications. Included are discussions of tests by stethoscope, magnetic action, X-ray, fatigue and impact. The characteristics of good and bad welds are described and actual inspection practice is taken up in detail. The book of 152 pages is bound in cloth. Throughout are many photographs, tables and diagrams. Price $1.75.

NEW EQUIPMENT

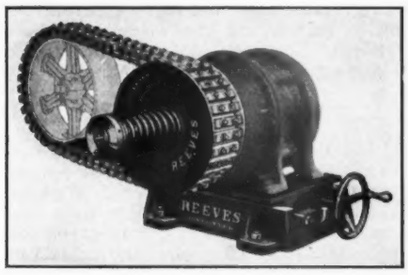
of interest to steam plant Engineers

Variable Speed Unit

A new variable speed unit has recently been placed on the market by the Reeves Pulley Company, Columbus, Ind. This unit, called the Reeves Vari-Speed Motor Pulley, is a simplified type of variable speed unit mounted directly on the motor shaft so as to form the driving element between the motor and the driven shaft.

The principle on which this pulley operates involves an assembly of two opposing cone-faced discs, one stationary and one sliding and an adjustable power compression spring, all of which is self-contained and mounted on the motor shaft; a special motor base with adjusting handwheel, by which the motor may be moved forward or backward; and a special type of belt, which contacts on its sides between the cone-faced discs and on its flat surface over the driven pulley.

When the motor is at the position on the special motor base nearest to the driven shaft, the V belt assumes the largest diameter formed by the cone-faced discs and the maximum speed is obtained on the driven pulley. By turning the handwheel, the motor is moved away from the driven pulley. This causes the V belt to assume a smaller diameter between



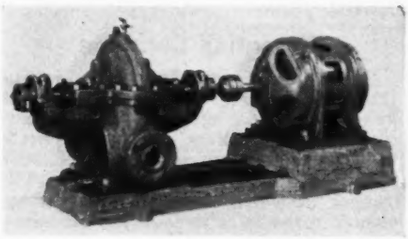
the cone-faced discs, the sliding discs moving laterally, but held in contact with the V belt by means of the compression spring. Thus, the speed of the driven pulley is reduced. When the motor is moved to the position farthest away from the driven shaft the V belt assumes the smallest diameter and the minimum speed is obtained on the driven pulley.

The speed control is infinite between a ratio limitation of 3 to 1. The horsepower transmitted is from fractional to seven and one-half. This unit is positive in transmission of power at all speeds. It is built in six sizes and is applicable to any standard motor of these sizes either AC or DC.

Centrifugal Pump

The Goulds Pumps, Inc., Seneca Falls, New York, have recently placed on the market a small, low-priced double suction, horizontally split-case pump unit.

The unit has exceptionally deep stuffing boxes and six rings of packing and water seal rings—a feature which reduces air and water leakage between sleeve and shaft. The unit has a maximum speed up to 3550 r.p.m. and a wide range of ratings. The casing is built for a maximum pressure of about 300 lb. per



sq. in. any part of which may be suction pressure.

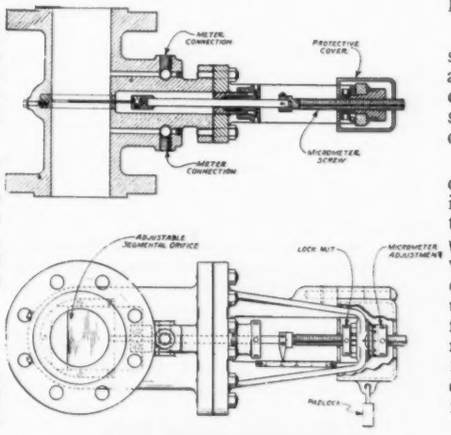
The pump will be classed as a stock unit. Casings, bedplates and impellers will be carried so that twenty-four hour shipments can be made. Shaft sleeves are standard equipment.

Further information regarding the design and construction details will be given by the manufacturer.

Adjustable Valve Orifice

The Bailey Adjustable Orifice has been designed by the Bailey Meter Company, Cleveland, Ohio, for fluid meter installations where it is desirable to obtain accurate measurements over a wide range of capacity. This product is particularly suitable for use with meters measuring gas or low pressure heating steam, since on these services the desired capacity is often dependent upon the season.

As illustrated the adjustable orifice consists of a flanged body with integral meter connections. It can be readily installed in a steam, water or gas line and connected to any differential head type of Fluid Meter. The adjustable orifice functions similarly to the commonly-used fixed type of Bailey segmental orifice. A

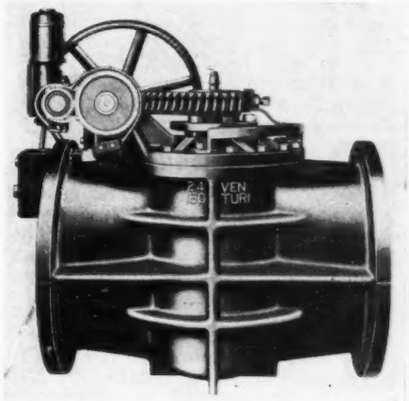


micrometer adjusting screw permits setting the height of the gate segment within .001 of an inch. When it is advisable to change the capacity of the meter, it is simply necessary to set the micrometer screw at the reading corresponding to the desired maximum capacity, as obtained from curve sheets furnished with the orifice.

The Adjustable Orifice permits changing the maximum capacity of the meter as much as 40 to 1 and consequently is equivalent to a multitude of fixed orifices. The change may be made in a few minutes' time without disrupting meter operation or diverting the flow through a bypass line.

Remote Control Valve

The Merco Nordstrom Valve Company, Inc., 11 West 42nd Street, New York, have developed and adapted Remote Control to Nordstrom valves. The quarter turn for full opening as well as the lubricating features of the valve make it particularly adaptable to Remote Control. Many of these valves are now installed in natural gas and manufactured gas systems and are operated from a central compressor station or office. The illustra-



tion shows a 24 in. Plug Valve equipped with a Cutler Hammer Unit.

Welding Flux

Cromaloy Flux, one of the important items in the line of Oxweld welding fluxes distributed by The Linde Air Products Company, 30 East 42nd Street, New York, has been developed especially for use in welding the chromium-containing alloys more generally known commercially as stainless steels or rustless irons.

Because of the excellent corrosion-resisting properties of these chromium-iron alloys, they are being used more and more extensively, and welded products in constantly increasing variety are being fabricated from these alloys.

The ordinary fluxes used for welding or brazing are not satisfactory in welding stainless steel or rustless iron because they will not dissolve the infusible oxides, consisting chiefly of chromium oxide, which tend to form on the molten surface of these alloys. A satisfactory flux for use in welding these alloys must be sufficiently fireproof to protect the molten metal and hot metal adjacent to the weld from oxidation, and at the same time correctly compounded to dissolve the refractory chromium oxide with ease.

Because of its high solvent power for chromium oxide, and its high resistance to heat, Cromaloy Flux is especially prepared for this type of work, and its use will insure best results in welding these special chromium-iron alloys.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Corrugated Expansion Joint

A pamphlet recently issued by the E. B. Badger & Sons Company describes the new Badger Self-Equalizing Corrugated Expansion Joint. The metal selected for Badger Expansion Joints is Everdur. The composition of this metal is 96 per cent copper, 3 per cent silicon and 1 per cent manganese. This composition provides a metal having all the advantages of copper, plus a much greater resiliency and durability and with tensile strength of mild steel. Other features claimed for this joint are—absence of maintenance because no packing is used—compactness and ease of installation—monel sleeve for use with superheated steam—choice of welding end or flanged end joints. 4 pages, 8½ x 11—E. B. Badger & Sons Company, Boston, Mass.

Expansion Joints

The Croll-Reynolds Engineering Company have issued a pamphlet describing the Flexodisc Expansion Joints. These expansion joints consist of a flexible heat-treated alloy steel expansion element welded to flanged heads or welding ends. These are guided in relation to each other by an internal sleeve in order to permit only longitudinal movement. The expansion element is suitable for many special applications such as a flexible connection in machinery, furnace flues, etc. Tables of dimensions are included. 4 pages, 8½ x 11—Croll-Reynolds Engineering Company, Inc., New York.

Inverted Open Float Steam Trap

Circular No. 242-A published by the Crane Company describes its new Inverted Open Float Steam Trap. This trap is the first of a series of Crane New Style Steam Traps which after having successfully passed exhaustive service tests are offered to the trade. This trap has been designed to meet the demand for a small inexpensive, yet very efficient trap for draining small steam heated units used in industrial plants. This trap embodies the principles which are necessary in a successful steam trap, keeping in mind simplicity of design, minimum number of parts, proper materials, low first cost and low maintenance cost. Tables and several illustrations are included. 8 pages, 5½ x 8½—Crane Company, 836 S. Michigan Avenue, Chicago, Illinois.

Lock-Forged Construction

Bulletin No. 206 has recently been issued by Alco Products, Inc. This bulletin describes the new lock-forged construction recently developed for application to shell and tube heat transfer equipment and particularly where high pressures and high temperatures are met. All the metal comprising the pressure-resisting structure of lock-forged units is either rolled or forged. The bolted joints are in every case heavily reinforced and do not depend on any weld. They are capable of withstanding enormous stresses and can be pulled up on gaskets until there is no possibility of a leak. 4 pages, 8½ x 11—Alco Products, Inc., 220 E. 42nd St., N. Y.

Preventing Corrosion

Bulletin 1238 just published by The Dampney Company of America describes its protective coatings for preventing corrosion of power plant equipment. Corrosion and the requirements for effective corrosion prevention are discussed. The manner in which the protective coatings manufactured by The Dampney Company and marketed under the trade name Apexior, meet the requirements for effective prevention of corrosion are pointed out and evaluated. Apexior is easily applied to boiler and economizer tubes. 16 pages and cover, 8½ x 11—The Dampney Company of America, Hyde Park, Boston, Massachusetts.

Speed Reducers

Bulletin 51 issued by the W. A. Jones Foundry & Machine Company describes the details of design and construction of the Jones Herringbone-Maag Speed Reducers. Information on operation, maintenance, prices, and speed reducing capacities is included. 12 pages, 8½ x 11—W. A. Jones Foundry & Machine Company, 4401 Roosevelt Road, Chicago, Ill.

Steam Trap

The Armstrong Steam Trap is described in a new pamphlet issued by The Armstrong Machine Works. The outstanding feature of this steam trap is the new free-floating valve lever which brings to the steam trap an entirely new principle. This new mechanism was in actual service for nearly five years before it was offered as part of the Armstrong Steam Trap. 4 pages, 8½ x 11—The Armstrong Machine Works, Three Rivers, Michigan.

Turbine Lubrication

The Tidewater Oil Company has recently issued a book entitled Modern Lubrication for Steam Turbines. This book is divided into four parts, of which the first covers The Importance of Proper Lubrication, the second covers Turbine Development and Principles of Turbine Construction, the third covers Systems of Lubrication and Turbine Oil Requirements and Recommendations, and the fourth includes Suggestions for Care of Turbine Oils. The book is splendidly illustrated in color and is very comprehensive. Conversion and weight tables are shown. 40 pages and cover, 8½ x 11—Tidewater Oil Company, New York.

Variable Speed Unit

A pamphlet describing the Reeves Vari-Speed Motor Pulley has just been issued by the Reeves Pulley Company. The Reeves Vari-Speed Motor Pulley is a new and simplified type of variable speed unit. It is directly mounted on the motor shaft and forms the driving element between the motor and the driven shaft. The speed control is infinite between a ratio limitation of 3 to 1. The horsepower transmitted is from fractional to seven and one-half. The speeds are conveniently adjusted simply by turning a handwheel. Any desired speed within the range may be easily secured and maintained. The unit is positive in transmission of power at all speeds. It is built in six sizes and applicable to any standard motor of these sizes, either AC or DC. 6 pages—8½ x 11—Reeves Pulley Company, Columbus, Indiana.

Water Level Indicator

The Schutte & Koerting Company has issued a bulletin describing their Televisor. This instrument is an electrically operated water level indicator for boilers, tanks, and other vessels. The outstanding feature of the Televisor is the fact that the illuminated indicator has only an electric cable connection to the boiler and may, therefore, be installed at any convenient place in the boiler room, control room or elsewhere in the plant. Complete information on the construction and operating features of the three separate elements making up the Televisor are included. 8 pages, 8½ x 11—Schutte & Koerting Company, Philadelphia, Pa.

Welded Pipe Outlets

The Bonney Forge & Tool Works have recently issued Bulletin WT12-A describing the Bonney Drop Forged Wedolets and Thredolets. These joints have been designed to make Tee joints easily and economically. They are individual fittings, designed to be installed by welding them to the main line. The more specific applications of each of these two welding outlets are stated and the manner in which they are installed is described in detail. Each of the steps in the installation process is shown by photographic illustrations. A table of the sizes in which these outlets are available is included. 8 pages, 8½ x 11—Bonney Forge & Tool Works, Allentown, Pennsylvania.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 409 boilers were placed in December according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930 Number	1930 Square feet	1931 Number	1931 Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	658	603,401
June	1,360	1,588,553	818	677,434
July	1,309	1,410,096	816	687,058
August	1,371	1,356,751	827	594,698
September	1,254	1,282,388	893	692,238
October	1,189	851,525	672	467,375
November	777	709,322	491	424,044
December	814	587,053	409	394,317
Total (Year)	13,166	13,469,893	8,017	7,229,618

TOTALS FOR FIRST 12 MONTHS AND NEW ORDERS, BY KIND, PLACED IN DECEMBER, 1930-1931

Kind	1930 No.	1930 Sq. ft.	1931 No.	1931 Sq. ft.	Dec., 1931 No.	Dec., 1931 Sq. ft.
Stationary:						
Total	12,909	12,336,486	7,855	6,730,172	400	382,840
Water tube	1,070	5,562,877	672	2,838,608	37	189,453
Horizontal return tubular	879	1,179,486	487	612,802	22	24,054
Vertical fire tube	1,140	340,470	626	173,106	40	13,214
Locomotive, not railway	167	145,251	103	87,030	7	4,808
Steel heating	8,081	3,546,144	5,201	2,300,394	269	127,285
Oil country	994	1,135,099	399	451,340	10	11,600
Self contained portable	438	310,027	302	233,888	14	11,989
Miscellaneous	140	117,132	65	33,004	1	437

MECHANICAL STOKER SALES

December stoker sales, reported to the Bureau of the Census by the 21 leading manufacturers, totaled 48 stokers of 11,072 hp.

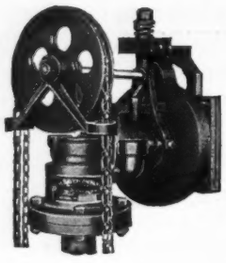
Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1929 Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
November	71	21,103	41	5,731	30	15,372
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365,664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	66	13,849	37	5,326	29	8,523
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
July	101	20,735	58	8,283	43	12,452
August	128	29,971	59	8,318	73	21,653
September	96	22,462	56	8,720	40	13,742
October	83	20,339	47	6,566	36	13,773
November	62	13,231	38	5,995	24	7,236
December	48	11,072	32	4,903	16	6,169
Total (Year)	988	247,812	510	77,391	478	170,421

PULVERIZED FUEL EQUIPMENT SALES

December orders for coal pulverizers as reported to the Bureau of the Census aggregated 2 pulverizers having a total capacity of 2,500 lb.

Year and Month	STORAGE SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent	DIRECT FIRED OR UNIT SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS														
1931														
January	2	2	..	60,000	1	51,177	704,000	8	4	4	40,500	9	42,970	412,675
February	1	..	1	40,000	1	29,100	375,000	2	2	..	8,000	1	7,570	75,000
March	2	2	..	60,000	..	.....	.....	13	13	..	122,000	8	93,960	1,404,000
April	2	2	..	60,000	1	34,300	592,000	9	8	1	49,250	6	46,300	538,200
May	..	..	..	.....	..	.....	.....	..	..	..	.....	..	.....	.....
June	..	..	..	.....	..	.....	.....	14	6	8	59,360	11	56,080	530,290
July	..	..	..	.....	..	.....	.....	11	8	3	114,600	8	117,000	1,088,980
August	..	..	..	.....	..	.....	.....	4	4	..	25,000	4	16,725	110,250
September	..	..	..	.....	..	.....	.....	3	2	1	9,250	3	2,682	86,600
October	1	1	..	30,000	1	11,894	126,000	1	1	..	2,650	1	3,000	24,000
November	..	..	..	.....	..	.....	.....	5	3	2	17,850	5	22,590	163,600
December	..	..	..	.....	..	.....	.....	2	1	1	2,500	2	7,850	22,000
Total (Year)	8	7	1	250,000	4	126,471	1,797,000	72	52	20	450,960	58	417,327	4,455,595
FOR INSTALLATION UNDER FIRE-TUBE BOILERS														
1931														
January	..	..	..	.....	..	.....	.....	6	..	6	6,000	6	7,500	53,350
February	..	..	..	.....	..	.....	.....	3	..	3	2,250	3	3,000	22,350
March	..	..	..	.....	..	.....	.....	2	1	1	2,750	1	3,004	22,500
April	..	..	..	.....	..	.....	.....	1	..	1	4,000	2	6,700	45,000
May	..	..	..	.....	..	.....	.....	3	1	2	3,800	3	6,000	27,000
June	..	..	..	.....	..	.....	.....	4	1	3	4,000	4	5,750	22,100
July	..	..	..	.....	..	.....	.....	5	3	2	3,900	5	8,000	47,700
August	..	..	..	.....	..	.....	.....	4	1	3	4,250	4	7,307	43,600
September	..	..	..	.....	..	.....	.....	4	4	..	4,350	5	5,000	22,500
October	..	..	..	.....	..	.....	.....	2	..	2	3,500	3	6,000	34,000
November	..	..	..	.....	..	.....	.....	..	..	..	.....	..	.....	.....
December	..	..	..	.....	..	.....	.....	1	..	1	500	1	1,500	7,000
Total (Year)	..	..	..	.....	..	.....	.....	35	11	24	39,300	37	59,761	347,100

Greater Cleaning Efficiency with BAYER SOOT BLOWERS



The exclusive Bayer feature of *full blowing force properly directed* is the reason why Bayer Balanced Valve-in Head Blowers do a better cleaning job with less steam, less time, and less wear.
In the Master Model "K-2" at the left, the valve, though truly part of the Blower Head, is operated entirely independent of the rotating element. The controls are together in the operator's hands. This Bayer principle insures full cleaning action with the minimum of steam used.
BAYER CHROMITE is our trade name for the Chromium Iron Alloy from which these blower elements are fabricated into continuous length of rolled tubing (not cast). The heat resistance of CHROMITE combined with air-cooling produces a soot-blower element that is immune to oxidation and warping even when exposed to temperatures as high as 2650 deg. fahr.

Our experience with effective soot-blower installations may be of help to you. We will be glad to answer your questions.

A BAYER for every type of boiler

There are other Bayer features fully described in our new catalog that are well worth your consideration. If you are interested in blowers for any type of boilers, tell us your needs.

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'A STITCH IN TIME SAVES NINE'
—*Repair Your Furnaces NOW!*

TIMELY repairs will save expensive furnace rebuilding later on. HYTEMPITE and MONO-LINE can help you very materially in carrying out a cost-saving furnace maintenance program. These Quigley products have cut costs in thousands of plants. Their unusual durability is a result of "built in" quality. Used regularly in over 40 countries.

HYTEMPITE — HIGH TEMPERATURE CEMENT

Fire Brick, bonded with HYTEMPITE, lasts longer and requires less maintenance. Repairs, when necessary, are quickly and economically made with this versatile refractory cement. Use Hytempite for restoring, reclaiming, pointing up, protective surfacing, monolithic baffles, etc. Always keep a drum or two of Hytempite handy for emergency repairs.

MONO-LINE — PLASTIC FIRE BRICK

MONO-LINE is a highly stable plastic refractory for building complete jointless furnace linings; for molding one-piece furnace doors, arches, jambs, bottoms; for refractory fill and backing in water walls; for general repairing and patching. Mono-Line forms a solid, monolithic structure that is air-and-gas-tight, and practically neutral as to expansion and contraction.

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Manufacturers of Industrial Specialties
56 West 45th Street, New York

Distributors with Stocks and Service in Every Industrial Center

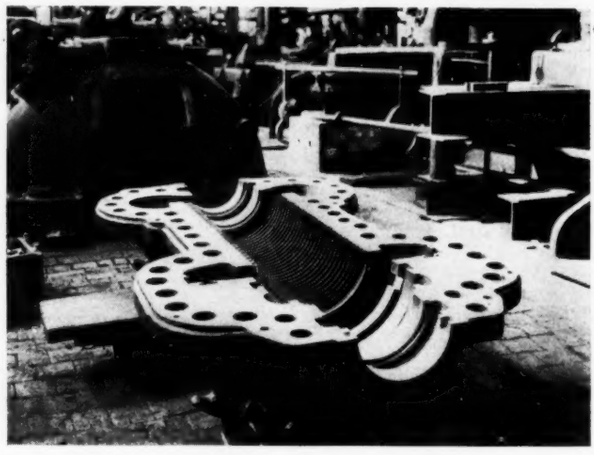
High Pressure Operation at Mannheim

(Continued from page 43)

The steam reheaters for each of the back-pressure turbines, dealing with the steam up to 294 lb. per sq. in. pressure and 480 deg. fahr. are divided into three compartments. The first two of these are supplied with a small amount of by-passed high-pressure steam, which is all condensed while heating the back-pressure steam from 480 to 563 deg. fahr. The third compartment completes the rise in temperature from 563 deg. to 660 deg. fahr. with delivery to the pressure mains. This final temperature rise is effected by the high-pressure steam which is passed through coils in the third stage of the reheater on its way to the high pressure turbines, this step reducing its temperature from about 860 to 806 deg. fahr.

As already indicated, the main trouble with the super-pressure boiler plant at Mannheim has been corrosion of the boiler tubes and while this has now been prevented, after developing also in the medium pressure plant, some of the causes are obscure.

It appears that the first super-pressure boiler had been running about 1000 hr. when a tube collapsed near the top, and two other tubes bulged.



Casing of 4800 kw. super-pressure turbine

On examination it was found the cause was an accumulation of iron oxides and sulphate of soda, together with a slight deposit of scale, resulting from trouble in a number of condenser tubes so that a small amount of the hard water used for cooling leaked through into the condensate returned to the boilers.

In order to guard against this trouble of film scale formation and local overheating of the tubes from future leaks, sodium phosphate was added continuously to the feedwater to give a slight alkalinity, which, however, resulted in an even worse trouble, eight tubes being damaged, while, as before, the material deposited consisted largely of iron oxide. A detailed investigation showed the

oxide of iron had not been formed locally but had accumulated in the upper portion of the tube, and this second trouble, following upon the use of sodium phosphate, seems to have been due to the loosening of the films of scale the particles of which lodged at certain spots and caused local overheating.

After this the boiler ran again for over 800 hr. and then another tube failed, and when this was repaired a 700-hr. run was achieved, followed by other failures. Meanwhile, however, in another boiler about 40 bulges had appeared in the tubes and as a result the use of sodium phosphate was abandoned. Subsequently the solution to this problem was found in the prevention of iron oxide formation through the reduction of the oxygen content of the feedwater to less than 0.1 mg. per liter. That is, the deaeration of the feedwater has to be carried out to very fine limits, while at the same time the feedwater treatment must be so efficient as to prevent any film of scale. This, of course, is in accordance with power station experience and practice of recent years in the United States. Obviously, the fact that these troubles took place in the super-pressure boilers was merely a coincidence and had nothing to do with the pressure, although, as stated, everybody believed at first this was the real cause and this hindered the solution of the problem for many months.

The whole paper by Dr. Marguerre contains so much concise information that it is difficult to give an adequate resumé. He points out, for example, that another common cause of corrosion is partially defective circulation in the boiler tubes especially when bubbles of steam are entrapped, while even now no final opinion has been expressed as to whether it is really advisable to use phosphate or not with the feedwater.

It may be stated that at the Meeting of the Association of Large Boiler Owners in Germany, already mentioned, some most interesting information was given concerning serious trouble that has been experienced, with six boilers at the Merseburg Synthetic Ammonia Works of the I. G. Farbenindustrie, operating at 676 lb. per sq. in. pressure, each boiler being 10,760 sq. ft. heating surface with a normal evaporation of 88,160 to 110,200 lb. per hr. As at Mannheim, but to a greater extent, several of the tubes collapsed, and in this case it was proved that the main cause was defective circulation, which was due to the entrapping of steam bubbles in the tubes, with the resultant formation of oxide of iron. When the tubes were operated under such conditions that a thin film of scale obtained then no corrosion took place, which of course is contradictory, since normally it is bad practice to have even a thin film of scale in super-pressure boilers.

Apparently under these super-pressure conditions, there also seems to be some tendency to minor dissociation of the steam in contact with the metal, forming oxides of iron, although considerable differences of opinion exist on the matter in Germany, as well as in the United States.

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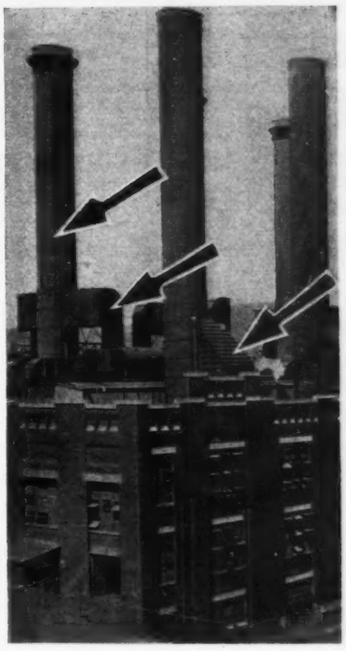

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